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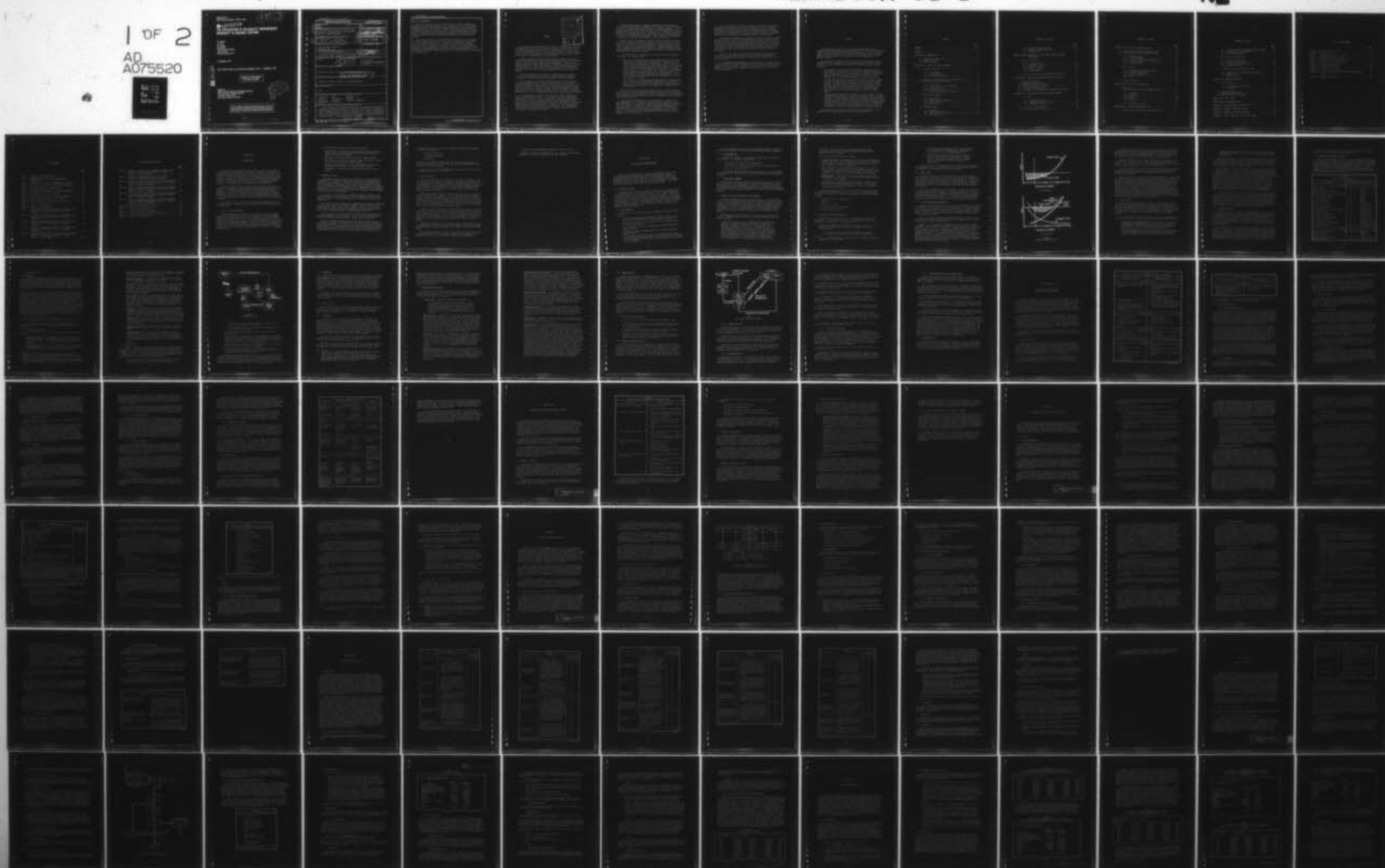

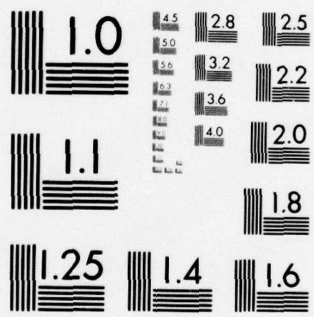
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THE APPLICATION OF RELIABILITY IMPROVEMENT WARRANTY TO DYNAMIC SYSTEMS

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4 September 1979

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The Reliability Improvement Warranty (RIW) is currently used within the Department of Defense to provide an incentive to contractors to design and produce equipment that will have a low failure rate, as well as low costs of repair following failure in field or operational use. Current applications of RIW have generally been restricted to initial production procurements of relatively small, transportable avionics equipment. → over

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The RIW concept has potential applications for dynamic systems (e.g., transmissions, gearboxes, engines, etc.) procured by the U.S. Army Mobility Equipment Research and Development Command (MERADCOM). However, dynamic systems may differ from avionics in design and maintenance concepts, transportability features, and deployment and utilization philosophy. Therefore, current criteria for using RIW and current guidelines for developing RIW terms and conditions should be reviewed and adapted for this new class of systems.

This effort identified several differences between the characteristics of dynamic systems and those of RIW avionics equipment that are not emphasized in current RIW guidelines. RIW application criteria for dynamic systems were also developed. An existing life-cycle cost (LCC) model was modified to address quantitative features of dynamic systems that should be considered in an economic analysis of RIW versus organic maintenance. Case studies were developed to demonstrate the use of the RIW selection criteria and the LCC model.

SUMMARY

The Reliability Improvement Warranty (RIW) is currently used within the Department of Defense to provide an incentive to contractors to design and produce equipment that will have a low failure rate, as well as low costs of repair after failure in field or operational use. Current applications of RIW have generally been restricted to initial production of relatively small and transportable avionics equipment.

The RIW concept has potential applications for dynamic systems (e.g., transmissions, gearboxes, engines, etc.) procured by the U.S. Army Mobility Equipment Research and Development Command (MERADCOM). However, since dynamic systems may differ from avionics in design and maintenance concepts, transportability features, and deployment and utilization philosophies, current criteria for using RIW and current guidelines for developing RIW terms and conditions require review and adaptation for this new class of systems.

This report summarizes the results of investigations to develop criteria for assessing the applicability of RIW to dynamic systems and guidelines for preparing RIW terms and conditions for these systems.

The requirements of the Magnuson-Moss Warranty Act, which applies to qualifying consumer products that cost more than $15, and the Defense Acquisition Regulation (DAR) section on warranty are each outlined to provide an introduction to the RIW concept. The goals and structure of RIW, as applied to avionics systems, are presented and two examples of current RIW applications are discussed in detail: the U.S. Air Force's AN/ARN-118 TACAN, and the U.S. Army's AN/ASN-128 Lightweight Doppler Navigation System.

The environments in which avionics RIWs are used are compared with those of typical dynamic systems. This comparison is made to identify differences that prevent, limit, or otherwise restrict the application of existing RIW practices to dynamic systems. These comparisons are made on the basis of information obtained in visits and discussions with several MERADCOM offices, with manufacturers of commercial and military dynamic systems, and with several other service activities. The principal areas where differences were identified included equipment design, operation, maintenance, and procurement scenario.

Several manufacturers of commercial equipments that are similar to those developed or purchased by MERADCOM were visited to identify the range and scope of commercial warranty practices for dynamic components. Commercial warranty practices present the buyer with an opportunity for reduced materiel (and perhaps labor) costs. However, the cost avoidance aspects of warranty are a minimum attraction to those buyers who are concerned mainly with the cash flow aspects of ownership. Parts and service information and availability are the principal concerns of this latter group.

Several service procurements of dynamic systems with RIW-like requirements were reviewed to illustrate the scope of previous efforts and, when possible, to identify the resulting experience. This information was then used as a basis for developing RIW guidance. Equipments covered in this survey included Army warranties for vehicles, a container handler procurement at MERADCOM, portions of the Blackhawk helicopter, and hydraulic pumps purchased by the Navy and Air Force.

On the basis of our investigations, two forms of RIW are identified as applicable to dynamic systems:

- The first is an RIW similar to those used for avionics, but whose requirements are tailored to accomodate the differences that are present in the dynamic system's procurement. In this case, the entire system (or subsystem) is covered by the RIW. Those portions of the system which would normally be removed from an end item for repair by the DS (or for exchange with GS or depot) are returned to the contractor for repair under RIW. Generally, only preventive maintenance and inspection tasks will be conducted by crew or operator personnel. or by organizational level mechanics. During RIW, the ranges of maintenance tasks at organization, DS, and GS are reduced to a minimum.
- The second form is "depot-only" RIW, denoted RIW-D. Under an RIW-D plan, the contractor's maintenance responsibility is limited to those repairs which require depot capabilities. Other maintenance activities are accomplished at the appropriate organization, DS, or GS activity.

As with avionics RIW, the goal of these plans is to provide the contractor with the greatest possible opportunity to learn from field failures of his equipment. This plan provides both the incentive and the opportunity for reliability growth, maintenance procedure improvements, and subsequent reduced life-cycle costs.

Under RIW-D, more responsibility for maintenance is transferred to Army organizations; the contractor's opportunity and incentive to learn about and improve his equipment's reliability and maintainability characteristics are reduced. However, when depot maintenance tasks represent a significant part of an equipment's repair requirements, or when other reasons (such as high costs of transporting subsystems that are easily repaired at lower levels) make RIW unattractive, the RIW-D may provide an alternate use of the concept.

A set of application criteria are developed that permit a qualitative assessment of the suitability of RIW (or RIW-D) for a specific program. These criteria (developed on the basis of criteria that were originally developed for avionics equipment) address the peculiar features of dynamic systems that are identified in this investigation. Guidance for developing warranty terms and conditions for dynamic systems is also presented.

A methodology for performing an economic evaluation of RIW is presented. Economic evaluation consists of determining the difference between the expected life-cycle cost for a system that uses RIW and the expected cost for a system that is supported under normal organic maintenance. A previously developed life-cycle cost model was modified for use with dynamic systems. Cost categories that were determined to be relevant to this analysis are identified and sample model outputs illustrate the economic evaluation methodology.

The use of the RIW application criteria and the life-cycle-cost model is illustrated with sample applications to two MERADCOM equipments: a 60 kW diesel generator and a hydraulic actuator system (which is part of a larger end item).

It is recommended that MERADCOM use these guidelines to identify test-case procurements for dynamic systems. When such test procurements are made, appropriate data collection and analyses activity should be initiated to evaluate the quality of RIW implementation and to assess the value of RIW in these applications.

PREFACE

This final report describes the work performed by ARINC Research Corporation between September 1978 and September 1979 under Contract DAAK70-78-C-0020. The project engineer was Dr. Richard Kowalski. This work was performed for the Product Assurance and Testing Directorate at the U.S. Army's Mobility Equipment Research and Development Command (MERADCOM) at Fort Belvoir, Virginia.

The authors are indebted to many individuals within Government and industry for their cooperation and initiative during this effort. Although there are too many individuals to identify, three groups deserve special attention.

- The MERADCOM project managers and laboratory personnel were more than generous in allowing us to discuss RIW concepts with them, in describing the products and procurements for which they were responsible, in identifying and providing background material on their programs, and in facilitating industry and Government contacts.
- The U.S. Army 4th Infantry Division (Mechanized), provided us with an excellent opportunity to observe the repair process for dynamic systems. The DARCOM Logistics Assistance Office at Fort Carson, Colorado, scheduled meetings with personnel responsible for repair and maintenance of several hundred wheeled and tracked vehicles. These discussions provided a practical view of the day-to-day operations that occur far from a contractor's plant or project office.
- Industry supplied much useful information for this effort. We had opportunities to meet with a variety of corporate personnel involved in warranty administration, marketing, engineering, sales, and quality assurance. Through candid discussions we exchanged information on the RIW concept and on current corporate and industry warranty trends. Industry personnel openly expressed their views on the possibilities and concerns of the RIW concept and provided us with a variety of documentation related to current equipments and warranty practices.

Finally, we wish to thank our contract technical monitor, Mr. Glenn Stewart, for his suggestions and support throughout the effort.

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SECTION ONE

INTRODUCTION

The Reliability Improvement Warranty (RIW) is currently used within the Department of Defense (DoD) to provide an incentive to contractors to design and produce equipment that will have a low failure rate and will be economical to repair following failure in field or operational use. Under an RIW, a contractor's responsibilities for reliability and maintainability performance and cost are extended into the field environment. RIW applications in DoD have generally been restricted to initial production procurements of relatively small, transportable avionics equipment.

The RIW concept has potential application to dynamic systems (e.g., transmissions, gearboxes, and rotating and reciprocating engines) procured by the U.S. Army Mobility Equipment Research and Development Command (MERADCOM). Dynamic systems may differ from avionics systems in design and maintenance concept, transportability, and deployment and utilization philosophy. Therefore, the current criteria for using RIW and the guidelines for developing an RIW require review and adaptation for this new class of systems.

This report presents criteria for assessing the applicability of RIW to dynamic systems. Guidelines for preparing an RIW for these systems are also developed.

1.1 SCOPE OF THE INVESTIGATION

RIW procurements are currently used by the DoD to improve equipment reliability and reduce support cost. The majority of these procurements conform with RIW guidelines issued by the Office of the Director, Defense Research and Engineering, in 1974. These guidelines address primarily the characteristics of avionics equipment and the environment in which avionics equipment is operated and maintained. The purpose of this investigation is to determine if current avionics RIW methodology is applicable to dynamic systems, and if it is applicable, what adaptation is required to accommodate dynamic systems.

The investigation included the following activities:

- Identification of quantitative and qualitative characteristics of dynamic systems that would prohibit the direct application of existing avionics RIW concepts
- Development of RIW application criteria for dynamic systems
- Modification of an existing life-cycle-cost (LCC) model to incorporate features peculiar to dynamic systems
- Discussion and development of case studies that illustrate the methodology for selection and economic analysis of RIW
- Establishment of guidelines for developing an RIW for dynamic systems

1.2 TECHNICAL APPROACH

ARINC Research reviewed the design, reliability, and maintainability characteristics of dynamic systems, together with their operational and maintenance environments (as compared with avionics), and examined procurement circumstances at MERADCOM. These reviews were accomplished through visits and discussions with MERADCOM activities; manufacturers of commercial and military systems; the 4th Infantry Division (Mechanized) at Fort Carson, Colorado; the U.S. Army Materiel Development and Readiness Command (DARCOM); and other major U.S. Army commands.

As a result of these efforts, we identified several significant differences between the characteristics of dynamic systems and those of RIW avionics equipment. These differences are not emphasized in current RIW guidelines.

The discussions with manufacturers, supplemented by information obtained in earlier interviews with a number of manufacturers and users of fixed ground equipment (which often contained dynamic systems), provided us with an overview of commercial warranty and support services available to the private sector and manufacturers' attitudes toward warranties.

We also surveyed military experience with vehicle warranties and RIW-related procurements involving dynamic systems; this survey consisted of document reviews and discussions with cognizant service activities.

From the information developed during the survey and from reviews of collateral documentation, guidelines for developing an RIW for a dynamic system were established. RIW application criteria for dynamic systems were also developed. An existing life-cycle-cost model was modified to include quantitative features of dynamic systems that should be considered in an economic analysis of RIW versus organic maintenance. These modifications

included the addition of three cost categories not generally considered in avionics LCC analysis:

- Preventive maintenance
- Overhaul/refurbishment
- Fuel/energy

In addition, the model's reliability-growth algorithms were modified to allow for reliability decay with time, and thus to represent wearout characteristics of dynamic systems.

Finally, case studies were developed to illustrate the use of the RIW application criteria and the LCC model.

1.3 REPORT STRUCTURE

Section Two presents an introduction to the types of warranties that are discussed in this report: the commercial warranty, the Defense Acquisition Regulation (DAR) warranty, and the RIW. The environment in which avionics RIWs are used is compared with typical dynamic system environments in Section Three. This comparison is made to identify differences that prevent, limit, or otherwise restrict the application of existing RIW practices to dynamic systems.

Section Four reviews warranty terms and conditions that are typically available for commercial dynamic systems and the administrative methods used to implement these warranties. Other commercial services available to enhance or support customer maintenance needs are also discussed. Section Five describes the Army's use of commercial-like warranties, together with service procurements of dynamic systems under RIW or other warranty arrangements. This review demonstrates the scope of service efforts in this area and presents certain lessons that have been learned.

Section Six presents guidelines for developing RIW terms and conditions for dynamic systems. Activity related to RIW is described for each program phase. A basic structure for RIW is presented and options for major specific features are discussed. This section also includes guidance for source selection. Section Seven presents a set of RIW application criteria that permits qualitative assessment of the suitability of RIW for a specific program.

Section Eight addresses the role that economic analysis plays in various program phases and provides a management summary of the LCC model that has been modified to permit analysis of the economics of RIW versus organic support.

Section Nine contains case studies that utilize the criteria of Section Seven and the model of Section Eight to demonstrate the methodology for determining whether or not to use RIW on a particular procurement.

Conclusions and Recommendations appear in Sections 10 and 11.

A number of appendixes supplement the text. Of particular interest is Appendix D, which is a user's guide for the LCC model.

SECTION TWO

THE RIW AND OTHER WARRANTIES

This chapter introduces three warranty concepts that are being used in commercial and DoD procurements: commercial warranties, Defense Acquisition Regulation (DAR) warranties, and the Reliability Improvement Warranty (RIW). Background is provided for a detailed discussion of the goals and structure of RIW as applied to avionics equipment. Two examples of avionics equipment procured with RIW are also presented.

2.1 COMMERCIAL WARRANTY

The Magnuson-Moss Warranty Act applies to qualifying consumer products costing more than $15. A basic provision of this act is that warranties for covered products must be available before a sale is made. Every term and condition of the warranty must be in writing; otherwise, it is not part of the warranty. In the case of product warranties, there is no difference between the terms "warranty" and "guarantee." Both words signify a promise by a manufacturer or seller to stand behind his product. There are two types of written warranties: full and limited. These terms have special meanings under the Warranty Act.

2.1.1 Full Warranty

The term "full", when applied under the Warranty Act, signifies the following:

- A defective product will be repaired (or replaced) free. This provision includes removal and reinstallation, if necessary.
- The defective product will be repaired within a reasonable time following the complaint.
- No unreasonable actions will be required of the buyer to obtain warranty service.
- The warranty applies to anyone who owns the product during the warranty period.
- If the product cannot be repaired (or the problem has not been corrected after a reasonable number of repairs), the user will have his or her choice of a new product or the money paid for the product will be refunded.

A full warranty does not have to cover the whole product; it may cover only part of a product or it may cover a product with certain exceptions.

2.1.2 Limited Warranty

A warranty is "limited" if it provides coverage that is less than a full warranty. For example, a warranty may:

- Cover parts but not labor for a replacement
- Allow credit on a repair, prorated by the use or time since sale
- Cover only the initial buyer

A product may carry more than one written warranty. Part of a product may be covered by a full warranty, while the rest may have limited warranty coverage.

2.1.3 Consequential Damages

Normally the purchaser's warranty rights include the right to "consequential damages": the company must not only repair the defective product but also pay for any damage caused by the product. However, in both full and limited warranties, a company can exempt itself from this responsibility by including in the warranty a statement that it does not cover consequential damages.

2.2 DEFENSE ACQUISITION REGULATION (DAR) WARRANTY

The use of warranties in military procurements is not a new concept; in this report such warranties will be called "standard" warranties. Traditionally, these applications have focused on defects in materials and workmanship and have provided the Government with additional time, following acceptance of an item, to determine conformity with specifications or discover defects in material and workmanship. When the Government does not specify the design, the warranty also extends to the usefulness of the design.

DAR Paragraph 1-324 defines the use of warranties for military procurement. Paragraph 1-324.1, "General", provides a background for this type of warranty:

> "A warranty is a promise or affirmation given by a seller to a purchaser regarding the nature, usefulness, or condition of the supplies or performance of services to be furnished. The principal purposes of a warranty in a Government contract are to delineate the rights and obligations of the contractor and the Government for defective items and services and to foster quality performance. Generally, warranties survive acceptance of the contract items for a stated period of time or use, or until the occurrence of a specified event, notwithstanding other contractual provisions pertaining to acceptance by the

Government. Thus, they allow the Government additional time after acceptance in which to assert a right consistent with the guidelines of this paragraph."

The criteria for using a warranty include:

- Nature of the Item - Consideration must be given to the complexity of the item, its degree of development, the difficulty of detecting defects before Government acceptance, and the potential harm to the Government if the item is defective.
- Cost - The benefits of a warranty must be related to its cost to the Government. Consideration should be given to the cost to the Government for correction or replacement by the contractor, by the Government, or by another source in the absence of a warranty.
- Administration - Effectiveness of warranty depends on the Government's ability to enforce it. For example, is the reporting system for defective items adequate?
- Trade Practice - Consideration should be given to whether or not the item is customarily warranted in the trade. In many cases, the cost of an item to the Government will be the same whether or not a warranty is included.

In preparing warranty provisions, the Government must state clearly the components and characteristics of an item that are warranted and the contractor's obligations for breach of the warranty. Areas to be covered include:

- Extent of contractor obligations
- Remedies
- Duration of coverage
- Notification process and timing
- Marking required on items

2.3 RELIABILITY IMPROVEMENT WARRANTY

The RIW is a form of warranty that is consistent with current DAR requirements. The following definition of RIW is taken from the "RIW Guidelines", issued by OSD in 1974 (Reference 2-1):

"A Reliability Improvement Warranty is a provision in either a fixed price acquisition or fixed price equipment overhaul contract in which:

(a) the contractor is provided with a monetary incentive, throughout the period of the warranty, to improve the

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2-1. __________, *RIW Guidelines,* issued by Director, Defense Research and Engineering, 13 August 1974.

production design and engineering of the equipment so as to enhance the field/operational reliability and maintainability of the system/equipment; and

(b) the contractor agrees that, during a specified or measured period of use, he will repair or replace (within a specified turnaround time) all equipment that fails (subject to specified exclusions, if applicable)."

The impact of RIW on a procurement is much greater than the impact of the standard warranty. To provide incentive to the contractor, several other aspects of the procurement may also be modified.

2.3.1 Goal of RIW

The goal of an RIW is to motivate contractors to design and produce equipment that will have a low failure rate and will be economical to repair following failure caused by field or operational use. In addition, after production and initial deployment, the RIW provides an incentive for contractors to improve the reliability of their equipment and to reduce repair costs during the period of warranty coverage in order to maximize their profits.

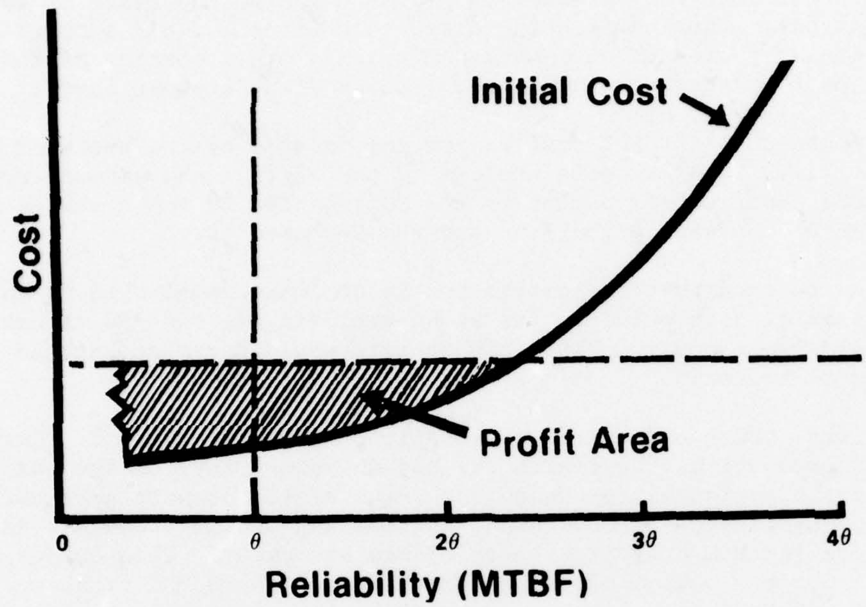
RIW is not a maintenance contract and does not require the contractor to provide routine periodic upkeep, regulation, adjusting, or cleaning. An RIW also does not cover components of a warranted item that are expected to require replacement under normal use during the term of the warranty (such as filters and light bulbs). Such items may be covered by separate provisions in the contract consistent with current laws and regulations.

2.3.2 Contractor Incentive Under RIW

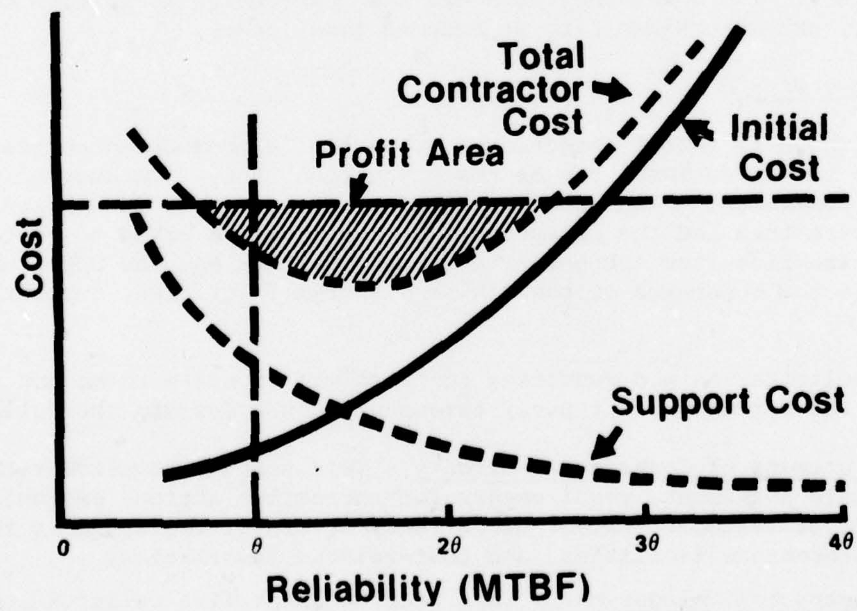
The core of the RIW philosophy is that during the period of the warranty coverage (at a firm, fixed price) contractors will be encouraged to improve the reliability and to reduce the repair costs of their equipment through the mechanism of "no cost" (to the Government) Engineering Change Proposals (ECPs). These ECPs must be consistent with Government procedures to preserve configuration control.

Figure 1 shows the economic situation for both the contractor and the Government under normal procurement practices and compares this situation with what occurs under the RIW concept.

Figure 1 (a) is a schedule of equipment cost as a function of equipment MTBF. If the contractor disregards all other factors and considers equipment cost strictly as a function of equipment MTBF, he can reduce this cost by reducing the quality of components, testing, inspection, or a number of other aspects of his program; these reductions will also reduce equipment reliability. The distance between the fixed-price contract line and the cost curve represents his profit at any achieved level of MTBF. Thus at any point on the cost curve the contractor is inherently, although not always knowingly, motivated to move to a lower-cost, lower-reliability (but higher-profit) point on the curve.



(a) Before RIW



(b) With RIW

FIGURE 1
ECONOMIC INCENTIVE OF RIW

Figure 1(b) illustrates the same situation with an RIW. Now the contractor must bid not only production prices but also the price of meeting RIW obligations. Thus he is being asked to share the field support costs over an initial period of equipment deployment. This portion of the contractor's cost is shown as the dotted line labeled "support cost".

The contractor's total cost is now represented by the U-shaped curve in Figure 1(b). This curve is the sum of the initial and support cost curves. The contractor's profit is now represented by the distance between the horizontal contract price line and the U-shaped curve.

It can be seen that the contractor is no longer motivated to move back down the initial cost curve as far as he would in the non-RIW situation, because below some optimum MTBF, his profits would decrease instead of continuing to increase.

Moreover, these curves are not static over the RIW period. During and even after production, the contractor has an opportunity, on the basis of his field repair experience, to change the shape of the support cost curve by developing no-cost-to-the-Government Engineering Change Proposals (ECPs) that improve the R&M characteristics of his equipment. This change tends either to move the bottom of the U-shaped curve toward the right -- to regions of higher reliability -- or to allow the contractor more profit at any given level of reliability if he can improve the maintainability of his equipment. The contractor thus achieves maximum profit by controlling and making appropriate trade-offs between acquisition and operation and support costs. The Government also has the opportunity to realize improved reliability and maintainability at reduced total costs.

2.3.3 Scope of RIW

RIW, which is usually negotiated as part of a production contract, applies to the operational use of the production items. Because of the long-term commitment being made by the contractor, RIW is identified as a separate cost item and the prospective contractors are asked to quote RIW as a separate line-item option. The Government then has the opportunity to evaluate the economics of the RIW versus organic or other support concepts.

The solicitation and resulting contract will contain terms and conditions for the warranty. A typical agreement should include the following:

- Statement of Contractor Warranty - This section identifies the basic agreement, requirements for corrective action, exclusions and limitations, extent of warranty coverage, requirements for maintenance facilities, and cost-related information.
- Contractor Obligations - This section identifies collateral contractor obligations regarding ECPs, warranty marking and seals, repair turnaround time and penalties, and data requirements.

- <u>Government Obligations</u> - This section identifies administration, timely approval of ECPs, and data to be provided to the equipment manufacturer.

Under RIW, a contractor is often required to maintain a secure storage area at his repair facility. Repaired items are placed in this facility and field demands for spares are sent to the contractor, either directly from a field user or through an item manager. The contractor provides both a depot storage facility and a repair capability.

The RIW applies to the Line Replaceable Unit (LRU) level when applied to avionics equipment. An LRU is that part of a system or subsystem that is removed from an aircraft after failure. Most avionics systems covered by RIW contain three or more LRUs. During the RIW period, the LRU becomes the lowest level of replaceable item at the using organization. The service will stock only LRUs (and perhaps items such as interconnecting cables) but will not provision items within an LRU. All failed LRUs will be returned to the contractor for processing under warranty. Under RIW, user and field maintenance organizations will have no capability to repair items within an LRU. The detailed manuals, training, and provisioning normally required to provide unit and organizational support will be delayed until the end of the RIW period, when the design is expected to be more mature and more stable as a result of contractor improvements.

In summary, the objective of RIW is to motivate and provide incentives to the contractor for better design for reliability and reduced repair costs. This objective is met through a firm-fixed-price contract that permits a contractor to repair all field failures and, after he has learned about his equipment's R&M characteristics, permits that contractor to generate no-cost ECPs that can save him and the Government money. The Government returns complete LRUs to the contractor and often defers purchase of detailed manuals, training, test equipment, and detailed provisioning.

2.3.4 <u>The MTBF Guarantee</u>

An MTBF guarantee is included in many RIW contracts, but it is stated as a separate requirement. The MTBF guarantee requires the contractor to guarantee that a stated MTBF will be achieved by the equipment in the operating environment and specified a measurement procedure that will be used to estimate field MTBF. If the guaranteed level is not met, the contractor is typically required to institute corrective action and additionally to provide consignment spares at no cost to the Government until the MTBF improves.

While RIW provides an incentive for R&M achievement through the contractor's repair activity commitments, the MTBF guarantee places specific emphasis on reliability because the contractor may be obligated to provide consignment spares to relieve pipeline shortages that may result from low MTBF. Because an MTBF guarantee represents a significant additional data collection and administration effort beyond that required for RIW, the investigation of MTBF guarantee applicability to dynamic systems was not

a part of this effort. However, the concept is mentioned to illustrate the scope of DoD avionics procurements using RIW.

2.3.5 Avionics Procurements Using RIW

Table 1 lists a number of current avionics equipments that have been procured with RIW. It also notes if the equipment has an MTBF guarantee and identifies the contractor who is producing the equipment. The largest service commitment to RIW has been made by the Air Force, in terms of both numbers of systems and total dollars obligated to RIW. The following sections will examine the requirements of two of these procurements in greater detail: the Air Force's AN/ARN-118 TACAN and the Army's AN/ASN-128 Lightweight Doppler Navigation System (LDNS).

TABLE 1
AVIONICS EQUIPMENT UNDER RIW

Equipment	RIW	RIW/MTBF	Contractor
Air Force			
ARN-118 TACAN		X	Collins
Inertial Navigation System		X	Delco
Attitude and Heading Reference System		X	Lear Siegler
Low Cost Omega Receiver		X	Dynell
C-130 Hydraulic Pump	X		Abex
Airspeed Indicator	X		Bendix
F-16 Radar Antenna	X		Westinghouse
F-16 Radar Low Power RF	X		Westinghouse
F-16 Radar Digital Signal Processor	X		Westinghouse
F-16 Radar Computer	X		Westinghouse
F-16 Radar Transmitter		X	Westinghouse
F-16 Flight Control Computer	X		Lear Siegler
F-16 Heads Up Display	X		Marconi-Elliott
F-16 Heads Up Display Electronics		X	Marconi-Elliott
F-16 Navigation Unit	X		Singer-Kearfott
Army			
ARN-123,R1963 VOR/ILS/MB		X	Bendix
APN-209 Altimeter	X		Honeywell
ASN-128 Lightweight Doppler Navigation System		X	Singer-Kearfott

2.4 THE AN/ARN-118 TACAN

2.4.1 Background

The ARN-118 TACAN represents the largest (in terms of number of units and dollars) DoD procurement containing extensive RIW provisions and an MTBF guarantee. The TACANs are short-range navigation systems that provide range and bearing data for aircraft navigation. In the early 1970s the Air Force inventory included approximately 10,000 TACAN sets, the majority of which were obsolete tube-type designs with an MTBF of approximately 100 hours.

In 1971, a feasibility study indicated that industry could produce a TACAN set that had a 1,000-hour MTBF and cost no more than $10,000 per set. On the basis of this study, an RFP for a development contract was issued in mid-1972. The RFP included an option for RIW whereby the contractor would be responsible for repair of any units that failed during the warranty period. Two contractors completed the development program, and their development equipments were subjected to extensive ground and flight tests. These contractors subsequently competed for the production award. In July 1975, the production contract, including RIW, was awarded to Collins Radio Corporation (a division of Rockwell International). The production contract (F19628-76-C-0144) included an initial production lot of 1,000 sets, with three production-year options for up to 7,500 additional sets. All production options were subsequently exercised. The TACAN has four LRUs in its most common configuration.

The contract includes an MTBF guarantee that begins at 500 hours and increases over the warranty period to 800 hours.

A case history of this procurement is included in Reference 2-2, Chapter 8. Reference 2-3 discusses this program from the contractor's point of view.

2.4.2 RIW Terms and Conditions

This section identifies the principal features of the RIW terms and conditions:

- Statement of Warranty - Each TACAN set will be free from defects in design, material, and workmanship, and will operate in its intended environment in accordance with specifically identified documents.
- Warranty Coverage - For the initial production lot of 1,000 sets the warranty ends four years after the last set is accepted. For all production options the warranty ends one year later.

2-2 Balaban, H.S. and Retterer, B.L., *Guidelines for Application of Warranties to Air Force Electronics Systems*, ARINC Research Corporation Publication 1451, December 1975.

2-3 Hauter, A.J., and Strempke, C.W., *TACAN RIW Program*, 1978 Proceedings Annual Reliability and Maintainability Symposium, Los Angeles, Calif., January, 1978, pp. 62-65.

- Repair Test Procedure - A limited repair-test procedure for repaired units is in force. The contractor will not be required to perform the complete acceptance test for each return.

- Unverified Failures - The contractor's liability for unverified failures is limited to 30 percent of all returns. Thus a maximum risk is established to protect the contractor.

- Exclusion - There is a presumption that each unit returned to the contractor's facility during warranty is covered under the warranty, with the following exclusions: acts of God, fire, explosion, submersion, aircraft crash, combat action, and external physical damage caused by mistreatment. The contractor is not responsible for consequential damages.

- No-Cost ECPs - No change-in-contract-price ECPs to improve R&M are encouraged. ECPs must conform to MIL-STD-480 where applicable and are considered to be automatically approved by the Government 35 days after submittal unless they are specifically disapproved by that time. The contractor must supply modification kits to the Government at the end of warranty to enable the inventory to be brought up-to-date.

- Usage Rate - This parameter, which strongly influences the number of returns, cannot be known exactly at the time of bid. Rather than state a fixed value or ask the contractor to estimate it, the contract includes an adjustment formula to account for variations from the 68-hour-per-month best estimate used as a pricing standard.

- Shipping Costs - The Government will pay shipping costs both ways; therefore, the contractor need not project the specifics of field deployment and will not be responsible for the cost of shipping unverified failures.

- Escalation Clause - The contract includes a clause to adjust for abnormal price fluctuations; this clause will apply to warranty costs.

- Turnaround time - The contractor has an average of 15 days to repair returned units. This time starts when the failed LRU is received at the contractor's facility and ends when a repaired LRU is placed in the secure storage area. The contractor must pay liquidated damages if this average is not met over a six-month period.

2.4.3 Material Flow

Figure 2 illustrates the material flow associated with a typical RIW repair action. When an aircraft returns with a report of TACAN failure, equipment built-in test is used to fault-isolate to the failed LRU on the aircraft. That LRU is then removed from the aircraft and replaced with a flight-line spare. No lower level of disassembly is permitted while the TACAN is under RIW. Then the following actions occur:

- The suspected failure of a warranted LRU is tested by military personnel at the using activity to verify the failure.

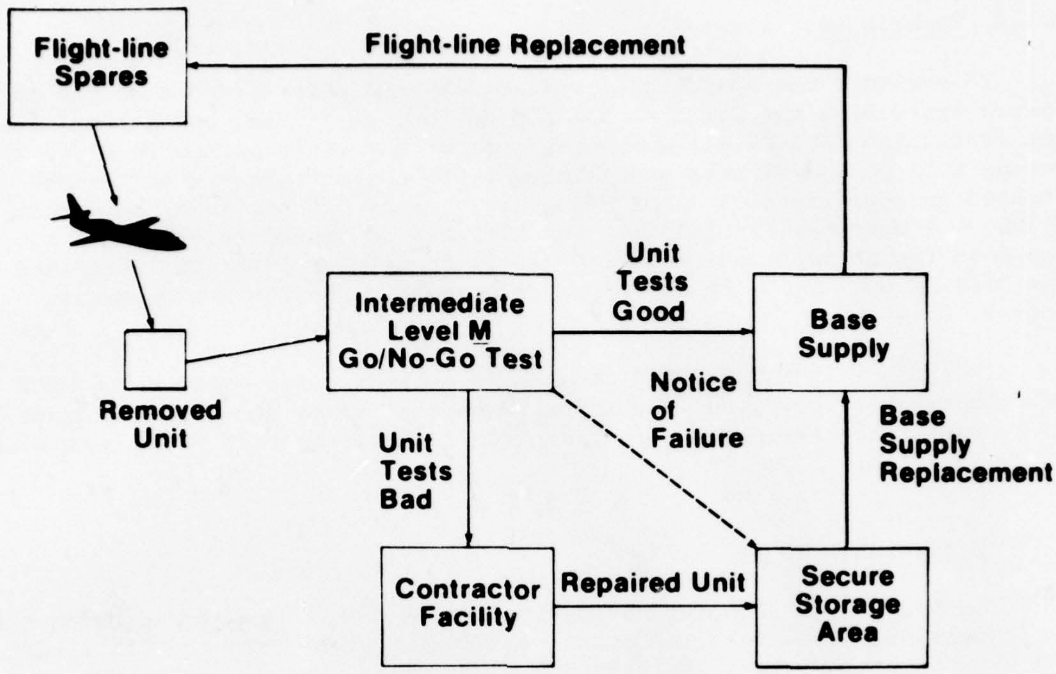


FIGURE 2
TACAN MATERIEL FLOW

- •• If the LRU tests "good", it is returned to service or sent to supply as a ready-for-issue spare.
- •• If the LRU tests "bad", it is shipped with appropriate data to the contractor for repair.

- The contractor receives the LRU and verifies the failure and warranty coverage.
- If the failure is not verified or is not covered by the warranty, corroboration by a Defense Contract Administration Services representative is obtained. In the event of an exclusion, a separate repair contract may be issued to the contractor.
- A covered failure is repaired at no additional cost to the Government, and required data records are prepared.
- The repaired LRU is shipped to the using activity, placed in the secure storage area maintained by the contractor, or sent to a location designated by the Government.

Concurrently with an LRU's being shipped to the contractor for repair, a notice is sent to the contractor's secure storage area by AUTODIN and a spare is sent to base supply before the failed unit physically reaches the contractor. This notification shortens the logistics pipeline significantly and reduces the assets needed to support a given flying schedule.

2.4.4 Experience

To evaluate the operational reliability and effectiveness of the TACAN before exercising the first production option, an initial operational test and evaluation (IOT&E) was conducted over a four-month period in 1976. During this period 52 sets accumulated 6,000 operating hours and demonstrated an operational MTBF of 544 hours. As of October 1978, more than 3,500 sets have been installed. The MTBF has continued to grow, and in the most recent measurement period (April to October 1978) the estimated set MTBF is over 2,000 hours (based on more than 850,000 set operating hours).

In summary, the TACAN RIW program is exceeding its goals. The MTBF is exceptionally high, and the short turnaround times and secure storage area provide the Air Force with logistics flexibility that would otherwise not be available.

2.5 AN/ASN-128 LDNS

The Lightweight Doppler Navigation System (LDNS) program is under the management of the Navigation/Control (NAVCON) Systems Project Office of the U.S. Army's Aviation Research and Development Command (AVRADCOM), Fort Monmouth, New Jersey.

2.5.1 Background

In June 1974, Full Scale Engineering Development (FSED) contracts were awarded to the Singer Company-Kearfott Division, and Teledyne Ryan Aeronautical, two of three competing Advanced Development (AD) contractors. In their production proposals, both contractors were required to bid on a Reliability Improvement Warranty (RIW) as an alternative to Army organic support for the initial deployment of the equipment. During source selection, RIW was selected as the LDNS initial support concept and, in December 1976, Singer Company-Kearfott Division was awarded the production contract (DAAB07-77-C-2126), which included RIW and an MTBF guarantee.

The production contract is for 200 sets, with options for 600 additional units. The LDNS has three LRUs. The development process for the LDNS RIW is described in References 2-4 and 2-5.

The LDNS, in conjunction with external inputs from a magnetic-heading reference and attitude-stabilization data system, computes position data for navigation in Universal Transverse Mercator (UTM) coordinates. The

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2-4. Kowalski, R., *Lightweight Doppler Navigation System (LDNS) Program*, ARINC Research Corporation Publication 1586, April 1977.

2-5. White, Col.R., and Kowalski, R., *Reliability Improvement Warranty and the Army Lightweight Doppler Navigation System*, Proceedings 1977 Annual Reliability and Maintainability Symposium, Philadelphia, Pennsylvania, January 1977, pp. 237-241.

LDNS provides present-position, range-to-destination, and velocity steering information for external display of hover velocities. In some aircraft the entire LDNS will be used to perform these functions. In other applications a portion of the LDNS [the Doppler Radar Velocity Sensor (DRVS)] will provide standard-format outputs that can be used with the computer and control-display units of other devices, such as the LORAN C/D Navigational Set, AN/ARN-114.

2.5.2 RIW Terms and Conditions

The RIW section of the LDNS contract is best reviewed by highlighting its provisions. A copy of the Terms and Conditions appears in Appendix A. Contract Data Requirements List (CDRL) DD1423, data item descriptions peculiar to RIW, appears in Appendix B.

- RIW Statement - The basic statement of the RIW is:

  "... The contractor warranty that each LDNS ... furnished under this contract will be free from defects in material, workmanship, and design, and will operate in its intended environment in accordance with contractual specifications for the warranty period set forth herein as it may be renewed under the provisions hereof."

- Warranty Period - Each LDNS is covered under the warranty, starting with Government acceptance of a system and extending to 48 months after the Initial Anniversary Date (IAD). The IAD is defined as the date of the successful completion of DT III PVT-G (Production Validation Testing-Government). Since PVT-G testing must be completed before this equipment can be formally released for installation in aircraft, this provision ensures that 48 months of RIW coverage is possible for each system and that RIW ends for all units on the same date. This arrangement has been made purposely to simplify planning for subsequent support activity.

- Exclusions - The contractor is obligated to repair or replace all LRUs except when failure is caused by fire, explosion, submersion, flood, aircraft crash, enemy action, or mistreatment. The contractor must present clear and convincing evidence to substantiate a claim that a returned LRU is not covered under the warranty. A separate contract is to be negotiated for repair of excluded returns. The contractor is not responsible for consequential damages.

- Unverified Failures - The contractor will be reimbursed $200 for each good LRU returned in excess of 24 returns or 25 percent of all returns, whichever is greater, over a 12-month interval. The $200 value is an estimate of contractor costs for processing good returns; the 25-percent figure represents an estimate of the LDNS false-return rate. The contractor can use this rate as an upper limit for pricing.

- ECPs and Configuration Control - Contractor-initiated ECPs to improve R&M at no change in price are encouraged under the RIW. Normal MIL-STD-480 procedures will apply, except that each such ECP will automatically be incorporated in the contract after 35 days, unless the contractor is notified of its nonapproval within that period. These ECPs must be installed in all new production LRUs and in all LRUs returned for repair under the RIW. To assure that it will be possible to bring the inventory to a standard configuration at a reasonable price upon the expiration of the warranty, the contractor is required to submit a schedule of modification-kit prices that are effective through the RIW expiration date.

- Operating-Hour Adjustment - The contractor is advised to bid the warranty price on the basis of a utilization rate of 20 hours per month for each system in the Government inventory. A method has been developed for estimating actual operating time from electrochemical indicator readings and shipping/receiving dates of returned units. A contract price-adjustment formula is provided, and it will be used for deviations greater than 10 percent from the 20-hour-per-month "pricing standard".

- Government Obligations - To the extent possible, the Government is required to verify failures before they are returned to the contractor, furnish failure-circumstance data, and use appropriate packaging. However, in the event that any or all of these conditions are not met, the warranty will remain in effect for such returns.

- Miscellaneous - The RIW also contains provisions for labeling and seals, price adjustment for lost LRUs, serial number record-keeping, and technical manual requirements.

- Turnaround Time - For each six-month period, there is a specified turnaround time -- the interval between the arrival and joint inspection of an LRU and the time it is subsequently repaired and moved to a secure storage area. Initially, the contractor has an average of 30 calendar days to complete these tasks. In subsequent six-month periods, this time is reduced until, after 18 months, he has an average of 15 calendar days to perform these actions. This reduction in turnaround time not only takes into account the learning process the contractor will undergo in repairing field failures, but also balances his learning process against the number of installs and spares in the field. Other adjustments in the turnaround-time requirement can be made on the basis of the equipment's MTBF. If turnaround time for a particular period is not met, the contractor is assessed a liquidated damage equal to $25 times the number of LRUs processed in the period times the number of days by which the turnaround time exceeds the specified average. Liquidated damages will not be collected for any measurement period if during the period the Government had sufficient assets in the bonded storeroom to meet each asset demand within a specified time limit.

2.5.3 MTBF Guarantee

The basic requirement of the MTBF guarantee is that the achieved mean time between failures (MTBF) of the LDNS be equal to or greater than 500 hours. A measurement process is specified in this part of the contract and measurements are made over six-month intervals beginning one year after the IAD. In the event that the measured MTBF is less than the guaranteed MTBF, the contractor shall furnish, at no additional cost to the Government, engineering analysis to determine the reasons for failure to achieve the guaranteed figure, corrective engineering design changes, and modification of units (as required).

If achieved MTBF measured in an interval is less than 400 hours, the contractor's turnaround time is reduced by four days. Conversely, if achieved MTBF measured in an interval is greater than 600 hours, the contractor's turnaround time is increased by four days.

Other RIW contracts with MTBF guarantees (such as the TACAN) have required contractors who fail to meet guaranteed values to supply additional assets to keep pipelines filled. This approach is not feasible with LDNS, since the production line for LDNS equipment may not operate through a major portion of the MTBF-guarantee measurement period. Thus the Army has chosen to modify the contractor's contribution to the logistics pipeline instead.

2.5.4 Warranty Data Requirements

Three data items are required to administer and support the RIW:

- A Data Collection and Analysis Plan describing how the contractor will accumulate, process, analyze, and report the information required under RIW.
- A semiannual Warranty Data Report containing records relating to population size, configuration, and repair history.
- An annual Warranty Effectiveness study containing the contractor's experiences and conclusions regarding the effectiveness of the warranty concept applied to this contract.

2.5.5 Logistics Support Under RIW

The logistics support for the AN/ASN-128 program is illustrated in Figure 3. A three-level system of maintenance support serves as the basis for aviation support (including avionics). The initial level of support is Aviation Unit Maintenance (AVUM). The AVUM corresponds roughly to a combination of the organization and Direct Support (DS) Unit in the Army's four-level concept. The Aviation Intermediate Maintenance (AVIM) level corresponds to the General Support (GS) level under the four-level concept.

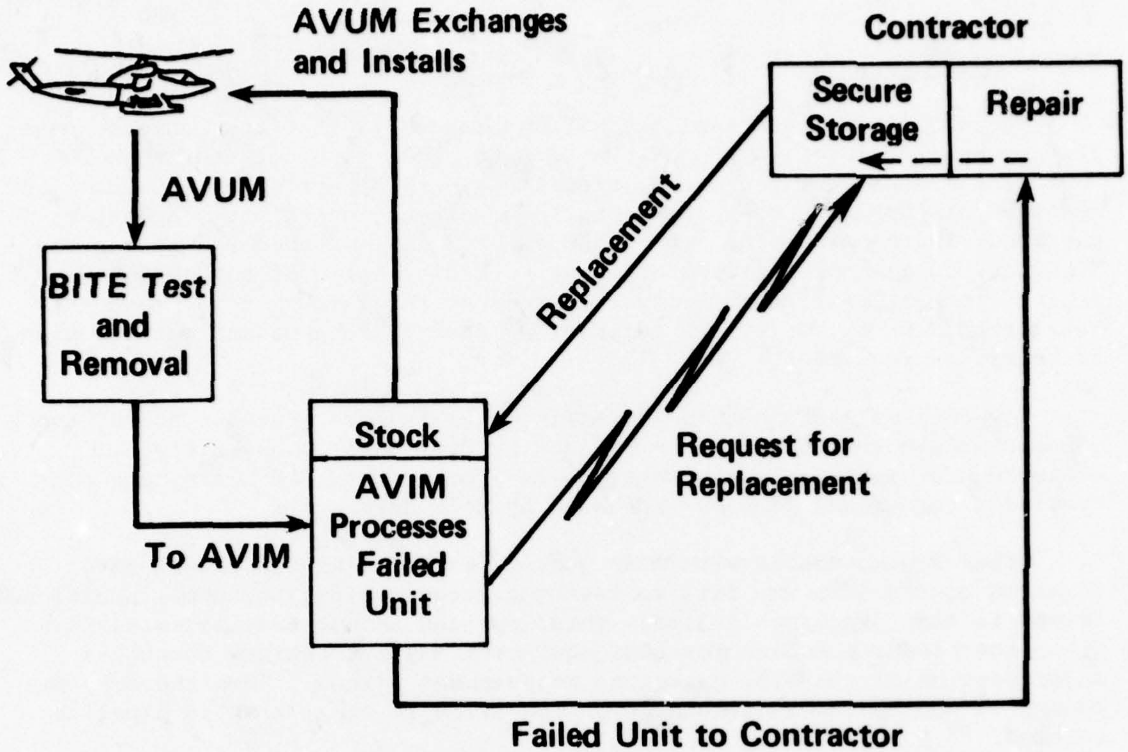

FIGURE 3
THE AN/ASN-128 SUPPORT CONCEPT

2.5.5.1 AVUM Processing

The AVUM tests the failed LRU using the BIT capability in accordance with the Technical Manuals. The AVUM then removes the failed LRU and takes it to the supporting AVIM. The Remove Date is recorded by the AVUM on the Installation/Removal Data Label attached to the LRU.

The AVUM completes a DA Form 2407 in accordance with the appropriate Supply Bulletin. One copy of this form accompanies the failed LRU back to the AVIM. This form must be completed accurately since the AVIM's only guidance in making out its own Form 2407 is the AVUM documentation.

The AVUM receives an operable LRU for the failed LRU from the AVIM. The operable LRU is used as a replacement and installed by AVUM in the aircraft. The Installation/Removal Data Label attached to the LRU is filled in during installation of the good unit.

2.5.5.2 AVIM Processing

The AVIM is not required to verify the LDNs failure and is not provided the capability to do so. The AVIM must, however, process the LRU for return to the contractor. This processing begins by ensuring that the Installation/Removal Data Label and AVUM DA Form 2407 are completed.

A new DA Form 2407 is prepared in accordance with the Supply Bulletin, with the AVUM copy used as a guide. Receipt copy #1 is placed in the container and accompanies the failed LRU to the contractor's repair facility. Copy #2 is mailed to the National Maintenance Point (NMP).

To maintain asset control, a DD Form 1348-1 must be prepared; a copy of this form is placed inside the container for shipment to the contractor. In addition, a copy of the DD Form 1348-1 is placed in an envelope attached to the outside of the container.

The LDNS Program has reusable containers for returning failed LRUS. These containers are retained to meet future shipping requirements.

The container with the failed unit and accompanying documentation is taken to the nearest U.S. Post Office and shipped by Air Parcel Post, Insured, Return Receipt Requested. The cost of this shipment is borne by the shipper.

If a unit was lost or destroyed in the field, the AVIM must prepare a DA Form 3906-R (Materiel Loss, Recovery Report) in accordance with the LDNS supply bulletin and AR 710-3.

When the container and documentation have been taken to the Post Office, the AVIM prepares a replacement request message, which is transmitted by the organization's supporting communications center. This message is sent to the contractor, who immediately ships a replacement unit to the AVIM.

At this point, the AVIM must complete a DD Form 173 (Joint Message Form) in accordance with the Supply Bulletin.

2.5.5.3 Contractor Processing

Before receiving the failed LRU shipment, the contractor will have responded to the Request for Replacement message. The replacement shipment carries a copy of DD Form 1149 inside the container and a copy in an envelope affixed to the outside. The DD Form 1149 will contain the MILSTRIP Document Number that is taken from the message. This number assists the AVIM in identifying the failure/replacement transaction for the field organization when it receives the shipment. This shipment is made by Air Parcel Post, Insured, Return Receipt Requested.

When the failed LRU shipment arrives, the contractor completes the return receipt request.

The shipment containing the failed LRU is jointly inspected by the contractor and the in-plant Government representatives. Damage in shipment (possible grounds for exclusion) is noted, and the failed LRU is sent to test and repair, after which it is packaged and sent to secure storage for issue as a replacement.

2.5.5.4 AVIM Processing of a Replacement Unit

Normally, the AVIM will receive a return receipt notice before its failed unit has arrived at the manufacturer's facility. If after three weeks the AVIM has not been notified, then the AVIM has the Postal Service trace the shipment.

When a replacement LRU is received from the contractor, the AVIM mails back the new return receipt notice to inform the contractor that the shipment has arrived. Government plant representatives will institute a tracing action if the shipment is not acknowledged within three weeks after leaving the contractor's facility.

The DD Form 1149 (with MILSTRIP number) affixed to the outside of the container is used to identify the original failure transaction.

The container is opened carefully and the LRU is inspected for damage in transit. If it has been damaged, it is returned to the contractor with DA Form 2407 and DD Form 1348-1, and a replacement message is sent -- the normal return procedure.

A good replacement LRU is placed in storage in its reusable container for future issue, after which the AVIM concludes the transaction by closing out the DA Form 2407, Maintenance Register, and inventory records.

Not all failure removals/installs are made at Army field installations. In the case of the LDNS, some maintenance activity will occur at prime aircraft manufacturer facilities. The materiel handling procedures are similar; however, documentation is peculiar to these types of organizations. A SF 368, Quality Deficiency Report, is used in place of the DA Form 2407 that normally accompanies a failed return to the contractor. A DD Form 1149, used in lieu of the DD Form 1348-1, also accompanies the failed LRU. The Specialized Repair Activity (SRA) or prime manufacturer will use the same type of reusable container as the field, and Air Parcel Post, Insured, Return Receipt Requested will be used for shipment. The replacement message approach is also used by these organizations.

2.5.6 RIW Experience

Initial production systems are now undergoing testing at Fort Rucker, Alabama, and Fort Campbell, Kentucky. Full scale production commenced in early 1979, and it is anticipated that a significant number of LDNS equipments will be deployed by late summer of this year. Extensive field data collection and RIW evaluation are planned at that time.

SECTION THREE

COMPARISON OF AVIONICS AND DYNAMIC SYSTEMS' ENVIRONMENTS

Section Two summarized the essential features of RIW plans that were developed for and applied to avionics (essentially electronics) equipments. In this section, we compare the environments in which avionics RIWs are used with environments of typical dynamic systems. This comparison is made to identify similarities that permit or differences that prevent, limit, or otherwise restrict the application of existing RIW practices to dynamic systems. This comparison also provides information that is used to develop RIW application criteria in Section Seven.

These comparisons are based on information obtained in visits and discussions with several MERADCOM offices, manufacturers of commercial and military dynamic systems, the 4th Infantry Division (Mechanized) at Fort Carson, Colorado, and other U.S. Army activities. A similar series of discussions with buyers and sellers of fixed ground systems (some containing dynamic systems) that were conducted for another study approximately one year ago provided additional data for this effort. Appendix C contains a list of organizations that were contacted.

The comparisons between avionics and dynamics systems are presented in Paragraph 3.1. In Paragraph 3.2, these comparisons are applied to two MERADCOM equipments.

3.1 AREAS OF COMPARISON

It was anticipated at the outset of this effort that the principal differences between avionics and dynamic systems' environments would be related to equipment design, operation, and maintenance. While there are major factors to be considered in each of these areas, our investigations also identified substantive differences in the procurement scenarios of avionics and many MERADCOM purchases. A fifth area, economics, was identified; this both combines and cuts across the other areas.

For each of these areas, Table 2 identifies conditions that have generally prevailed during the application of RIW to avionics; Table 2 also shows contrasting situations that may exist for dynamic systems.

TABLE 2
COMPARISON OF AVIONICS AND DYNAMIC SYSTEMS' ENVIRONMENTS

Avionics Systems	Dynamic Systems
Procurement Factors	
• Production follows development phases.	• Equipment is of commercial design or minimum adaptation of commercial design. • Equipment design is Government-specified. • Production purchase is from a reprocurement package.
• Developers compete for production contract.	• Only a single development contractor bids on production effort.
• Contract award represents the total buy, or contract contains production options necessary to make total buy.	• Solicitation and subsequent awards are made annually or biannually.
Equipment Factors	
• High cost density	• Low cost density
• Independent operation	• Dependent operation
• Single failure will initiate maintenance activity.	• Degraded operation possible
• Fragile	• Rugged
Operations Factors	
• Predictable usage	• Variable usage
• High maintanance-skill levels	• Lower maintenance-skill levels
• Overstress of equipment unlikely	• Overstress of equipment possible
Support Factors	
• No PMI	• Regular PMI
• No overhaul or on-condition maintenance	• Subject to overhaul or on-condition maintenance
• Centralized control through •• System project office •• System manager •• Item manager	• Diffuse control through command channels

(continued)

TABLE 2 (continued)	
Avionics Systems	Dynamic Systems
Economic Factor	
• Usage and quantity present contractor with opportunity to learn from field results and opportunity to make changes to increase profit.	• Incentives for improvement not very evident

The following subsections address the impact that the differences can have on the application of RIW to dynamic systems.

3.1.1 Procurement Factors

3.1.1.1 Development Background

Avionics RIWs are generally purchased as part of an initial production contract for equipment that is completing one or more development phases. Two or more developers are competing for the production contract; each is offering to produce his own design (although each may incorporate standard subitems in his design, e.g., power supplies). The RIW for the CONUS NAV VOR/ILS (AN/ARN-123) was part of a formally advertised two-step procurement that required military adaptation and packaging of a basically commercial design. But, again, each offeror was presenting his own design.

On the other hand, many dynamic systems are produced by a commercial production line. Quality and performance features of these systems are driven by the demands (or tolerances) of the marketplace. If a specific Government solicitation affects only a small percent of an offeror's annual production capacity for an item, there may be little or no incentive to produce and deliver anything but marketplace-driven quality. If the commercial design is adequate for the job, then standard inspection and acceptance methods could ensure that production quality levels are met; further, these methods would be simpler to administer than RIW.

When a design is based on either Government designs or a reprocurement package, the offeror may have limited capability to estimate the cost and risk of RIW, unless the offeror has also developed the reprocurement package. The RIW could be difficult to enforce if a contractor has met design package requirements and at the same time produced an equipment with low MTBF (in this case the contractor would have to satisfy his RIW obligations at a loss).

3.1.1.2 Quantity

The avionics procurements using RIW include quantities that are sufficient to meet military needs for several years. These quantities either are directly called for in the contract or are available through the

exercise of production options. This procurement approach reduces the possibility of multiple producers for an equipment and the mixed maintenance or supply policy that could accompany such a situation.

In contrast, many procurements of dynamic systems are for small quantities. Often these procurements represent low-rate initial production efforts that are intended to verify the integrity of a production package before holding a competition on a reprocurement package. Unless the usage rates for these items are high, a contractor will not see many failures under RIW and will have little incentive to improve his equipment.

3.1.2 Equipment Factors

The weight, space, power, and cooling limitations of helicopters and high-performance fighter aircraft often drive avionics designs. Thus the factors in this area (listed in Table 2) apply to a wide range of avionics equipments, independently of RIW. However, the differences between avionics and dynamic systems can affect not only the feasibility but also the administration of RIW requirements.

3.1.2.1 Cost Density

Historically, avionics systems have had a high cost density. The cliché that puts the cost of avionics at "$1,000 per pound" can occasionally produce reasonable estimates. Thus packaging, shipping, and transportation costs for avionics LRUs under RIW are only a small fraction of the equipment's value. In addition, individual LRUs are generally designed to weigh less than 35 pounds so that they can be moved by a single person.

Dynamic systems can be quite different. Cost densities of tens of dollars per pound are common. Thus the ratio of shipment value to shipment cost is much lower for these items than for avionics. Many dynamic items require two or more people or special equipment for handling, especially in a packaged state. Thus the feasibility of RIW, or any support alternative that increases equipment transportation and handling requirements, may be reduced for low-cost-density systems.

High-weight or-volume items may exceed shipment limits for certain modes of transportation (e.g., air parcel post). As a result, transportation options may be reduced for some dynamic systems, resulting in increased pipeline time if the RIW concept of returning LRUs is observed.

3.1.2.2 Independent Operation

Avionics equipments, especially those with RIW, generally operate independently of other aircraft systems. Although avionics equipments are linked to aircraft prime power and may be tied to a central aircraft computer or external sensors, the equipments often feed displays or other instruments that are covered under the same RIW. In many cases the equipments have a built-in-test (BIT) capability that makes end-to-end checks of performance independent of external systems.

On the other hand, the operations of many dynamic systems are dependent on other systems in various ways. For example, hydraulic systems may permit many types of interaction among their components, especially in the case of a component failure or contamination of the hydraulic fluid. When all members of an interacting set are not covered under the same RIW or when the interfaces between RIW and non-RIW items are only vaguely defined, there may be administrative difficulties in assigning fault when a failure occurs. This ambiguity can lead to high exclusion rates under RIW, since contractors will not be responsible for making repairs that are attributable to causes external to their equipment.

3.1.2.3 Degraded Operation

Single failures in avionics usually require a maintenance action at the earliest possible opportunity.

Failures of dynamic systems are often less clearly defined and, more important, less easily detected by the user or field maintenance organization. For example, is an engine generating "x" shaft horsepower? Is a pump moving "y" cubic feet per minute? Is the contamination level of hydraulic fluid out of tolerance? Few fault indicators in the dynamic world compare with the BIT found in most modern avionics. As a result, the judgment that an item has failed and, subsequently, estimates of mean time between failures (or mean miles, mean cycles, or whatever the applicable standard) can be influenced by subjective judgments that add risk to a contractor's estimate of the cost of RIW.

3.1.2.4 Ruggedness

Finally, one factor appears to favor the application of RIW to dynamic systems: systems' physical ruggedness. Although in practice problems with avionics damage incurred during shipment are minimal, the possibility is a constant concern. Shipping damage appears to be a relatively insignificant problem for dynamic systems.

3.1.3 Operations Factors

3.1.3.1 Usage Rates

The services have formal procedures for planning, developing, and scheduling aircraft flying time. Although the average flight hours per month differ for various classes of aircraft, these figures are projected and planned in advance of their occurrence. In addition, month-to-month variations are minimal since there is a regular need to maintain pilot proficiency. For these reasons, projected usage rates of avionics are normally available to a program office and can be used by an offeror as a basis for establishing his obligations under RIW.

Our discussions and observations of dynamic systems indicate that similar planning data are generally not available for many dynamic systems' equipments. Many items, such as construction equipment and generators, support troop exercises and activities only at certain times. After the

exercises or activities are completed, these equipments are often stored until they are needed again. For example, certain items (such as rock-crushing equipment) at Fort Carson had been used only once or twice a year, but during a current exercise these items operated 70 hours per week to accomplish their task.

Usage rates that are difficult to predict and that may experience wide swings from period to period present a problem for the RIW bidder. Unless an offeror has some estimate of equipment usage rates, he will have difficulty estimating return rates and, under RIW, identifying failure trends.

3.1.3.2 Personnel Skill Levels

Aviation (and particularly avionics maintenance) technicians are generally selected from personnel in the highest class of scores in standard tests. Thus the average skill levels for personnel who will maintain specific ground dynamic systems may be lower than for avionics maintenance personnel. It is not clear whether this difference will produce a positive or negative impact on RIW. On the one hand, ground dynamic system maintenance personnel may be more inclined to follow published RIW administrative procedures, thereby avoiding unauthorized repairs that would normally be paid for outside the RIW. On the other hand, these personnel may not appreciate the maintenance and supply impacts of RIW and, as a result, may attempt unauthorized repairs and thus establish an exclusion rate that is greater than expected.

3.1.3.3 Overstress Potential

Current avionics designs are generally not subjected to "overstress" conditions (operator actions that exceed the design limits of the item and thereby cause it to fail). While aircraft may be flown beyond specified performance levels, thereby inducing failures in the on-board avionics, such actions usually present grave safety risks to pilot and crew and occur only under most unusual circumstances.

On the other hand, many dynamic systems can be overstressed either intentionally or by omission. This factor is thus related to skill level. Some organizations we visited expressed the opinion that more than 50 percent of the dynamic system failures were induced by operators or other personnel. Improper start-up, warm-up, cool-down, or shutdown procedures may damage engines or accessories. Hydraulic systems, transmissions, and universals may be subjected to overloading, which may cause or hasten system failure.

3.1.4 Support Factors

3.1.4.1 PMI and Overhaul

Avionics equipments supported under RIW generally have no preventive maintenance and inspection (PMI) associated with them. Activities closest to PMI consist of lamp tests or periodic replacement of equipment-related batteries.

Dynamic systems, on the other hand, often require lubrication, fluid level and filter checks, and periodic visual inspections or tests that could produce on-condition maintenance. The principal impact of PMI on RIW occurs when the PMI is either not performed when required or not implemented properly. These oversights can either cause or hasten equipment failures. For example, failure to maintain appropriate levels of lubrication can cause or contribute to excessive wear rates of affected equipment.

Under RIW, a contractor must assume that appropriate PMI discipline will be maintained in the field. The RIW should exclude failures caused by poor PMI. Further, unless the contractor has some method to verify (at least on a sample basis) that PMI was properly performed, his bid must cover the expected cost of repairing failures attributable to poor PMI.

3.1.4.2 Centralized Control

In the Air Force, piece-part repair of an avionics equipment is usually accomplished at a single Air Logistics Center (ALC) in the Continental United States (CONUS). Support responsibility for that equipment will rest with either an item manager or, at certain times and under certain conditions, the System Program Office (SPO) that developed or procured the item or the aircraft System Manager (SM) who uses the items. Similar arrangements are in effect for Army avionics.

The situation is different for Army ground systems, which include the dynamic systems under consideration here. These systems are often repaired at the GS that supports the user. For commercial items the user, DS, or GS may deal directly with a local dealer to effect repairs or obtain spares. Thus basic information on equipment repairs is spread across a number of facilities. In addition, if the equipment is used at irregular intervals, periodic reports on repair activity are difficult to interpret because the underlying usage rates are variable.

3.1.5 Economic Factor

In avionics procurements that use RIW, sufficient failures are expected to provide a contractor with the opportunity to learn from field failure experience and to develop no-cost improvements that can benefit both the contractor and the Government. Many dynamic systems procurements may not provide this opportunity. Either the quantity is small, the usage rate is unknown or subject to broad variations, or operational/maintenance errors cause a high percentage of exclusions. All of these factors diminish the contractor's incentive and opportunity to meet the goals of RIW.

3.2 COMPARISON OF AVIONICS AND MERADCOM PROCUREMENTS

Table 3 illustrates these differences for specific RIW avionics and MERADCOM dynamic systems. The TACAN and the LDNS programs, discussed in Section 2, represent typical avionics equipment with RIW. The MERADCOM dynamic systems are represented by the 60 kW generator, which is procured by the DoD Manager for Mobile Electric Power (MEP), and the 50,000-pound

TABLE 3
COMPARISON OF AVIONICS AND MERADCOM PROCUREMENTS

AN/ARN-118	AN/ASN-128	Generator	Container Handler
Procurement Factors			
Competitive development and production bids by two contractors	Competitive development and production bids by two contractors	Government design specification released for fixed-price competition	Commercial chassis but competition by four developers for container handling portions
Initial purchase of 1,000 with options for 7,500	Initial purchase of 200 with options for 600	Periodic procurements dependent on DoD requirements	Options for up to 600 units
Equipment Factors			
Approximately $250/pound	Approximately $750/pound	Less than $5/pound	Less than $5/pound
Uses aircraft power and antennas; RIW covers control and display LRU	Uses aircraft power and may provide outputs to other systems, but RIW covers control/display LRU	Status and control panel used to monitor operation, but no BIT equivalent	Vehicle status and control panels used to monitor operation, but no BIT equivalent
BIT provides end-to-end check	BIT provides end-to-end check		
Operation Factors			
Solicitation recommended 68 operating hours/month across aircraft fleet for bidding purposes	Solicitation recommended 20 operating hours/month per installed unit for bidding purposes	Usage rate not identified in solicitation	Usage rate not identified in solicitation
Overstress unlikely	Overstress unlikely	Engine subject to overstress during operation and shut-down cycle	Engine subject to overstress during operation and shut-down cycle -- potential for overloading lift capacity
Support Factors			
No PMI required	No PMI required	PMI for engine	PMI for several subsystems (engine, brakes, transmission, hydraulic, etc.)
No on-condition maintenance	No on-condition maintenance	On-condition maintenance used	On-condition maintenance used
Item control through Warner Robins Air Logistics Center	Item control through Navigational Control Systems (NAVCON) Project Office at AVRADCOM	Major overhaul at Sacramento Air Logistics Center -- most repairs authorized at DS/DG levels -- spares from FSN system	Item repaired at DS/GS -- major overhaul facilities not yet determined
Economic Factor			
Expected 40-50 returns per month if only minimum MTBF is met on minimum-quantity purchased -- excellent opportunity to learn about system	Expect 8-10 returns per month if only minimum MTBF is met -- good opportunity to learn about system	Expected number of returns uncertain because of uncertainty about usage rate	Expected number of returns uncertain because of uncertainty about usage rate

Container Handler, which was procured by the Mechanical and Construction Equipment Laboratory. The container handler is a military adaptation of a commercial item (MACI) in that there was a competitive development effort during which each offeror designed a special container handler to mate with a commercial chassis of his choice.

There are differences between these two classes of systems in the areas of equipment, operations, and support factors. These differences indicate that although the generator and container handler may be candidates for RIW, the RIW terms and conditions normally associated with avionics will require extensive tailoring to produce an effective package. These systems are discussed again in Section Nine after selection criteria and an RIW economic model have been introduced.

SECTION FOUR

COMMERCIAL WARRANTIES FOR DYNAMIC SYSTEMS

Several manufacturers of commercial equipments similar to those developed or purchased by MERADCOM were visited during this investigation to identify the range and scope of commercial warranty practices for dynamic components. These visits follow by approximately one year a similar series of discussions with buyers and sellers of fixed ground equipments, some containing dynamic systems, that were conducted for another study. The information obtained in these visits provided additional insight and background on commercial practices. Appendix C contains a list of organizations that were contacted.

This chapter reviews warranty terms and conditions typically available for commercial dynamic systems, as well as administrative methods used to implement these warranties. Other services available to enhance or support customer maintenance needs are also discussed.

It is important to recognize that construction, material-handling, and power-generation equipments are sold in an extremely competitive marketplace. Warranty represents only one aspect of a manufacturer's sales strategy. For this reason, our discussions will illustrate the range of warranty alternatives that are available rather than concentrate on specific features offered by specific firms.

4.1 WARRANTY COVERAGE

Warranties for commercial items such as construction, materiel-handling, and power-generation equipment are often covered by the Magnuson-Moss Warranty Act, discussed in Section Two. Each commercial manufacturer has a warranty for his equipment that is included in the price of the equipment. During our visits, we collected several warranties for subsequent review. All were limited warranties. Table 4 summarizes the major points addressed in these warranties, and indicates the most common forms of available coverage.

In many cases, replacement or repair parts carry the same warranty as an original item. This provision can apply even to parts purchased after the original item is out of warranty.

TABLE 4 TYPICAL COMMERCIAL WARRANTIES FOR DYNAMIC SYSTEMS	
Feature	Types of Coverage
1. Who and what is covered?	• Original purchaser • Defects in material and workmanship
2. What will the seller provide?	• Repair or replacement parts at distributor's or manufacturer's option • Labor for installation • Labor for removal and installation • Repair at dealer or distributor facility • Repair only during normal working hours
3. How long is the coverage?	• Miles, operating hours, or calendar time from delivery • Miles, operating hours, or calendar time from "first substantial use"
4. What is excluded from the warranty?	• Mistreatment or neglect • Improper application • Improper installation • Malfunctions resulting from use of unapproved attachments
5. What are the limitations of the warranty?	• No repairs or replacement at field locations • No repairs or replacement made during premium labor hours • No obligation to incorporate improvements after sale • No liability for damage, loss of usage, or loss of income • Cost of compliance cannot exceed original value

Sometimes a manufacturer will exempt certain portions of an equipment from the warranty (e.g., tires or other systems produced by another manufacturer) and "pass through" to the customer a collateral warranty from the original manufacturer.

The terms and conditions listed in Table 4 serve to define the following:

- The extent and duration of warranty
- The seller's responsibilities
- The limitations on the seller's responsibilities
- The buyer's responsibilities (identified in the responses to question 4 in Table 4)

For a given transaction, warranty terms and conditions are to some extent negotiable, especially for items such as length of coverage or transferability to a third party. Deviations from the original warranty are normally subject to the manufacturer's approval. As such, they are screened by the seller to ensure that they are really necessary or beneficial to the user.

4.2 WARRANTY ADMINISTRATION

Commercial sales are frequently made through a network of authorized dealers (who may handle only one brand) or distributors (who will generally handle several brands). The dealer/distributor network will also act as a supply organization for the customer. This network, in turn, is supplied either directly from the manufacturer (and the manufacturer's major subcontractors or suppliers) or through regional parts centers.

The principal point of contact for the commercial customer is the dealer or distributor. Warranty claims are initially handled at that point. When a dealer or distributor provides warranty service, he is usually reimbursed by the manufacturer for parts and also receives a labor allowance depending on the task performed. Some manufacturers reimburse dealers and distributors for parts only. Therefore, the dealer or distributor adjusts the original sales price to cover expected labor costs under warranty.

4.3 WARRANTY INFORMATION FEEDBACK

At periodic intervals, dealers and distributors provide the manufacturer with reports of warranty activity. These reports include failed-part and cost information. Operating-time data were generally considered to be inaccurate and rarely available. Thus the analysis of warranty data is primarily an attempt to identify exceptional failure-frequency or cost trends. Occasionally, a manufacturer may ask the dealers and distributors to forward certain classes of failed parts. Often, the dealer or distributor, being closest to the customer, will report suspected problems to the manufacturer.

4.4 ADDITIONAL SUPPORT TO THE USER

A number of support services are available to the user both at the time of sale and following the sale. Although not directly related to warranty, these services are intended to increase customer satisfaction with the product. One goal of these services is reducing unscheduled maintenance. Another is better education of the customer in the full capability of the equipment and in more efficient operating and maintenance practices. Standard support activities include the following:

- Delivery and callback meetings - At or about time of delivery, dealer personnel meet with user personnel to discuss equipment capabilities and to illustrate typical operating and maintenance sequences, such as start-up and shut-down procedures and daily and weekly preventive maintenance activities. One or two callback visits are made in the next three months, both to check on how the equipment is being used and maintained and to answer questions.
- Publications - Operator and shop manuals and service guides are available to a buyer. In addition, for many classes of equipment the manufacturer may develop separate lubrication or preventive maintenance guides that will also include appropriate logs for record-keeping. These guides serve (1) to identify the range and scope of preventive maintenance requirements and (2) to allow the buyer to demonstrate that the equipment has been properly maintained in the event of a subsequent warranty claim.
- Training - Various manufacturers, either directly or through their sales network, sponsor operator and maintenance training and refresher courses and seminars for their customers. Often, this training is presented at either minimal cost or no cost to the customer.

4.5 ATTITUDES TOWARD WARRANTY

To the manufacturer, a warranty is a marketing and sales tool in a competitive environment. Warranties for a given equipment will change from time to time to reflect the demands of the marketplace, the experience of the manufacturer, and, more recently, legal developments (e.g., court awards in product liability cases). Through warranty, the manufacturer states his commitment to stand behind claims of a satisfactory or superior product and service organization. The manufacturer also gains an opportunity to learn about current and projected customer needs.

Equipment buyers have a variety of needs. Hence, attitudes toward warranty are equally diverse. At one extreme, a warranty offers a period of minimum repair costs following purchase (assuming that buyer obligations are met). This offer is a desirable feature for buyers with budget concerns. On the other hand, many equipments represent a major capital expense that is justified only by use in high-production or tight-schedule operations (which may be conducted at remote locations). In these cases equipment downtime must be minimized to ensure that production quotas, performance guarantees, or progress-payment requirements are met. Cannibalization may

be used to minimize the number of out-of-service equipments. Cash-flow analysis will take precedence over profit-and-loss statements. The cost-avoidance aspects of warranty are a secondary attraction to this group of buyers. Parts and information availability are of primary concern.

4.6 RELIABILITY IMPROVEMENT AND THE COMMERCIAL WARRANTY

As a basis for improving an equipment's reliability and maintainability (R&M) commercial warranty information is only one of many sources of data available to the manufacturer. Other sources include replacement-parts sales and trends, dealer and distributor reports, dealer repair and overhaul information, and buyer and user comments on equipment utility and performance. This exchange can identify areas in which existing products can be improved. However, such improvements will not normally be incorporated in previously sold items (see Table 4, item 5), although they could be reflected in better replacement parts or assemblies.

In summary, commercial warranty practices offer an opportunity for reduced material (and perhaps labor) costs if properly applied to service purchases. However, there appears to be little direct opportunity for influencing the design of an equipment or improving the reliability or maintainability characteristics of equipment purchased on a specific procurement.

SECTION FIVE

MILITARY WARRANTIES FOR DYNAMIC SYSTEMS

The Army has used commercial-like warranties for many of its vehicles. Each of the services has also procured dynamic systems under conditions similar to those imposed by RIW. These applications of warranty are reviewed in this section to show the scope of previous efforts and to identify the resulting experience and lessons learned. This information can provide a baseline for development of future RIWs for dynamic systems.

5.1 U.S. ARMY

5.1.1 Vehicle Warranties

The General Services Administration (GSA) is responsible for purchasing most of the commercial vehicles used by civil agencies, such as the Departments of the Interior, Agriculture, and Labor, and the U.S. Postal Service. Generally, GSA buys commercial vehicles weighing less than 10,000 pounds that are used by the Department of Defense (DoD). Vehicles weighing 10,000 pounds or more are purchased by the Army's Tank-Automotive Materiel Readiness Command (TARCOM) for all DoD activities, e.g., Army, Air Force, and Navy.

Government contracts for commercial vehicles normally include warranties which ensure that certain defects in material or workmanship will be corrected by the manufacturer for a specified period. The warranty period usually begins when the vehicle is delivered and continues in effect for a stipulated time period or mileage amount, e.g., 12 months or 12,000 miles, whichever comes first.

Billback agreements may be established as part of the vehicle warranty clause in the contract. These agreements allow the Government to make warranted repairs and obtain reimbursement from the manufacturer when it is impractical to return vehicles to an authorized dealer. This feature was not included in the commercial warranties that were reviewed in Section Two.

The United States General Accounting Office has periodically reviewed the contracting and administrative aspects of Army vehicle warranties (References 5-1 and 5-2).

In Reference 5-1, it was recommended that procurement offices and warranty control points do the following:

- Obtain warranties for diesel-powered and heavy-duty trucks comparable to those provided to the public
- Establish billback agreements to recover the costs of warrantable repairs when it is not practical to return vehicles to a dealer
- Provide to vehicle users complete, current, and accurate information that explains the terms and conditions of warranties and use of billback agreements
- Evaluate periodically the effectiveness of the warranty enforcement systems

Reference 5-2 is a follow-up report to determine what had been done as a result of the earlier report and to identify further potential improvements. This report indicated that TARCOM had adopted a new warranty provision for commercial vehicle contracts. Vehicle manufacturers were responding to the provision, which included the following:

- Warranty terms equal to those offered the general public
- An extension of the basic warranty period from 12 to 15 months
- A billback agreement to allow the Government, with prior permission, to make warranted repairs and obtain reimbursement from the manufacturer when it is impractical to return vehicles to an authorized dealer

However, the GAO reported that users were not aware of the extent of this improved warranty coverage or of procedures to implement billback agreements. This latter point is particularly important where dealer facilities are not designed for servicing larger Government vehicles or when dealers are located at a distance from the vehicles' operating site. The report concluded that TARCOM actions should improve the Government's use of warranties but that further improvement in providing information to users was required.

In summary, these reports establish the utility of warranties for vehicles but point out that improvements in administration would increase benefits to the Government.

5-1. __________, *Savings Expected from Better Use of Truck Warranties by Government Agencies*, GAO Report PSAD-75-64, March 20, 1975.

5-2. __________, *Vehicle Warranties: Greater Efficiency for Government By Using Commercial Practices*, GAO Report PSAD-78-53, December 15, 1977.

TARCOM continues to evaluate the problems of warranty administration. Information is disseminated to users through a variety of documents, including Supply Bulletins and Materiel Fielding Plans. Warranty features are also made a part of Materiel Fielding Plans and a part of Operation Handoff, which represents the formal transfer of equipment from the readiness command to the using command. However, the educational and cultural process that will bring out the full cost benefits of warranty will require regular attention to and feedback of administrative results at the user level. The following factors illustrate the complexity (and hence the confusion) that can occur at the user level:

- Many vehicles are supplied to an organization through annual or biannual purchases. At any given time, the mix of vehicles may have varying warranty expiration dates.
- Within a single vehicle under warranty, coverage may differ among the components on the vehicle. For example, diesel engines may be covered for greater periods than other items.
- When organizational or DS levels are not securing replacement parts directly from a dealer, the replacement part is ordered by FSN and may not be a warranted item. Thus if a subsequent repair is required for the same component, the repair would not be under warranty and must be obtained through normal supply channels. An alternative is to maintain dual stock bins for warranted vehicles, which would be difficult to administer.

5.1.2 MERADCOM's Container Handler

The Mechanical and Construction Equipment Laboratory at MERADCOM recently awarded Contract DAAK70-78-B-0411 to Caterpillar Tractor Company for a container handler capable of handling 50,000-pound loads. Four manufacturers completed development programs to design a special container handler that would mate with a commercial chassis of the manufacturer's choice. The equipment is therefore considered a military adaptation of a commercial item (MACI). Each of the development contractors competed for the production award. The winning bid resulted in a price of approximately $175,000 per unit. Options in the contract provide for as many as 600 units to be delivered over a five-year period, with the first production deliveries to begin in 1980.

The solicitation for the container handlers contained a warranty against defects in design, material, and workmanship, as well as conformance with specifications for a period of six months or 600 operating hours, whichever occurred first. Anticipating that many of these items would be placed in storage before initial use, the provisions also required that in the event of storage after acceptance the warranty period would not begin until the items were removed from storage or until six months after acceptance, whichever occurred first. An additional option provided for a 15-month or 1,500-operating-hour warranty in lieu of the six-month/600-hour operating warranty. The Army accepted the 15-month/1,500-operating-hour warranty after the winning bidder offered an extended warranty period for an additional price of $406 per unit.

For each warranty repair, the contractor will supply parts and can either correct the failure on site or have the vehicle or parts returned to his plant. In the latter case, the cost of labor and transportation is borne by the contractor. The Government may elect to repair a failed warranted item itself. In this case, the cost of labor will be borne by the contractor and will be computed at the prevailing rates for the geographical area.

5.1.3 Blackhawk Helicopter

The Blackhawk helicopter production contracts contain RIW-like agreements in two areas: certain dynamic components manufactured by the aircraft prime contractor, Sikorsky Aircraft Division of United Technologies Corporation; and the T-700-GE-700 engines, manufactured by General Electric Corporation.

5.1.3.1 Reliability Assurance Warranty for Sikorsky Components

The Sikorsky production contract (DAAJ01-77-C-0001) for Blackhawk contains a Reliability Assurance Warranty (RAW) clause for the components listed in Table 5. Sikorsky and Boeing completed development programs and the Army held competitive fly-offs of these equipments prior to production award. During this time, it was realized that over the first three years of deployment, the successful contractor would be required to supply depot-level support for his helicopter. To limit the cost of such support, an analysis was performed to identify the likely cost drivers of each design and to negotiate the RAW before contract award under a fixed-price incentive agreement. The basic statement of warranty is:

> "The Contractor warrants, in accordance with the provisions and limitations hereinafter set forth, that it will accomplish depot level repair, as required, of the components set forth below (hereinafter called "Warranted Components") during the period(s) of this warranty under the pricing arrangement as set forth in Section E of this contract."

The contract contains an initial production quantity of 15 helicopters, with second-and third-year production options for 56 and 129 helicopters and various fourth-year production options. The RAW's Firm Target Price for the first three years of production is approximately $6.4 million. The RAW is in effect from August 1978 through March 1981 or for 57,000 flight hours, whichever occurs first.

Sikorsky is responsible for performing all depot maintenance in accordance with the depot manuals. The Army expects to incorporate this actual maintenance experience into the manuals that will ultimately be issued for depot use.

The RAW is designed, as much as possible, to have little impact on AVUM and AVIM activities. Impacts on manuals and requisition methods are expected to be minimal when transition from RAW to depot support occurs.

TABLE 5
BLACKHAWK COMPONENTS COVERED BY RAW

Component	Quantity per Aircraft
Main Gearbox Mid-Section Module	1
Main Gearbox Input Module	2
Main Gearbox Accessory Module	2
Intermediate Gearbox	1
Tail Gearbox	1
Swashplate Assembly (without scissors and expandable pin)	1
Drive Shafts	9
Couplings	11
Main Rotor Head Spindle Module	4
Main Rotor Blade (without pressure indicator, abrasion strip, de-icing elements, pressure valve, and tip caps)*	4
Tail Rotor Blade Paddle (without de-icing elements, abrasion strip, and tip caps)*	2

*The main and tail rotor blade abrasion strips are currently designated as field-repairable in the UH-60A UTTAS Maintenance Manual. In the event that these items are subsequently determined to be other than field-repairable, the provisions governing the inclusion of these items under this Reliability Assurance Warranty shall be the subject of an equitable adjustment and this contract modified accordingly.

There are several classes of exclusion in the contract; should any of these exclusions exist when a warranted component is returned for repair, the Government will fund the cost of such repair outside the RAW. The exclusions cover failure caused by the following:

- Battle damage, accidents, foreign-object damage
- Maintenance error (e.g., maintenance not in accordance with maintenance and operating manuals)
- Pilot error
- Operation of equipment outside prescribed limits
- Contaminated fluid (fuel, hydraulic, nitrogen, or lubrication)
- Certain other specified conditions

In addition, the contractor maintains configuration control over the warranted components, and various conditions are identified to further define contractor and Government rights.

Up to the second quarter of 1979 one failure covered under RAW had occurred in an intermediate gearbox. Detailed analyses were not available, but it appears that the failure was caused by insufficient lubrication within the component.

5.1.3.2 General Electric Limited Warranty

Each Blackhawk uses two General Electric T-700-GE-700 engines. These engines were purchased sole source and provided as Government Furnished Equipment (GFE) to the Blackhawk prime contractor. The warranty in General Electric Contract DAAK50-78-C-0001 covers each of 53 engines produced under Contract DAAJ01-77-C-0002. The major subsystems of these engines are listed in Table 6. Each engine is covered for 500 total engine hours or until three years after the Government accepts the first engine, whichever occurs first. This warranty was negotiated with a fixed price, with a ceiling obligation established at $2.265 million. Repairs are excluded if the engine has been

- Improperly installed
- Subjected to misuse, neglect, or accident
- Operated in area of armed conflict
- Subjected to foreign-object damage or corrosion/erosion that causes a failure
- Subjected to other specified conditions

Also excluded are any failures caused by parts (original, replacement, repair, or otherwise) provided by any source other than the contractor.

The Government receives a 100-percent parts warranty allowance (PWA) for any parts replaced during a warranty repair action during the first 250 hours of running time for each engine. The allowance also covers any parts suffering direct or resultant damage during the warranty repair action. Engines that require removal to depot for repair of a warranted failure during the first 250 hours of running time are repaired at no charge. For warranted repair after 250 hours but before 500 hours on each engine, the PWA or the Engine Repair Overhaul Discount (EROD) is prorated by the fraction

$$\frac{500-T}{250}$$

where T is the engine operating time in hours.

A Reliability Incentive (RI) clause is also included in this warranty. Engines that run beyond 500 hours up to 750 hours without warranted failure

TABLE 6 BLACKHAWK ENGINE COMPONENTS COVERED UNDER WARRANTY
Ignition exciter
Output shaft assembly
Power takeoff drive assembly
Gas generator turbine rotor
Stage 1 nozzle
Combustion liner
Gas generator turbine stator
Power turbine module
Accessory section module
Fuel boost pump
Lube pump
Sequence valve
Particle separator blower
Anti-ice valve
Hydromechanical unit
Electrical control unit
History recorder

receive an RI of 5 percent of the negotiated engine target price times the fraction

$$\frac{T-500}{750}$$

If only portions of an engine accumulate 500 hours without a failure, the RI is then seven percent of the price of those items times this same fraction. There is a limit of $530,000 on the total amount payable to the contractor under the RI clause.

5.1.3.3 Summary of Blackhawk Warranties

The Blackhawk warranties illustrate the two warranty concepts that have been discussed in earlier sections. The engine warranty has many of the features of a commercial warranty. The PWA represents a form of bill-back arrangement. Incentives for no-cost improvements are limited since a ceiling is placed on both the contractor's liability and the potential payback under the RI clause. However, cost-avoidance features are present, as is an opportunity to learn from failures under this initial warranty and to incorporate that information into future production lots (perhaps through submission of cost ECPs).

The Sikorsky RAW incorporates many features of the RIW concept. The mixture of Army and contractor maintenance responsibilities represents a trade-off between complete contractor involvement in maintenance and cost-effective material allocation. In addition, the current arrangement should facilitate a simpler transition period. The potential for reliability improvement is somewhat inhibited by the mixed maintenance arrangement. However, there appears to be a good opportunity for developing more efficient depot maintenance procedures.

5.2 U.S. NAVY: THE ABEX PUMP

Contract N00383-73-C-3318 between the Navy's Aviation Supply Office and Abex Corporation provides for Failure Free Warranty/Reliability Improvement Warranty (FFW/RIW) on 258 pumps (168 installed items, 65 spares, and 25 in a rotable pool). The term FFW was applied in 1967 to the first DoD long-term fixed-price warranty contract whose price was calculated on the basis of program of continuous reliability growth (see Reference 5-3).

The Abex model AP26V-5-02 engine-driven hydraulic pump is installed on the Navy's F-14 fighter, one on each engine (2 per aircraft), as contractor (Grumman) furnished equipment. The pump is rated to deliver 200 HP continuously and is capable of generating 300 HP for intermittent peak loads. The pump was considered a new state-of-the-art design, about twice the size of previous designs for military aircraft applications of primary engine-driven pumps.

The basic pump cost $2,900; the warranty was $478 per year per unit of population. This price was lower than the anticipated cost for the usual mode of support with no warranty. This warranty cost excludes cost of depot support equipment.

The contract was priced on the basis of a projected flying-hour program and specific target removal rates. The F-14 flying-hour program translated into a total of 387,000 pump operating hours, and the mean time between returns (MTBR) for the pump was targeted to be 500 operating hours per return at the start of the first year, increasing by 50 hours per year to an end point of 750 operating hours per return. There were no exclusions in this contract.

At a mid-1975 program review it was established that MTBF had grown to more than 800 operating hours per return. At that time, 104 pump returns provided insight into equipment maintenance and operational characteristics. The removal rate was lower than anticipated (1.25 returns per 1,000 hours versus 1.33 returns per 1,000 hours anticipated at the end of the contract). The lower removal rate provided a higher level of fleet supply support within the established inventory levels (no not-operationally ready air-

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5-3. __________, Contract N00383-67-C-3101 between Aviation Supply Office and Lear Siegler, Inc.

craft as a result of stock outages of the pump). Much of the growth is attributed to a strong contractor effort. Several changes have been made to improve field reliability and to reduce removal rates in items such as front bearing shaft seals, stroking piston, and shaft coupling. These changes were made within the scope of the FFW/RIW.

By mid-1977 the MTBF had grown to more than 1,150 hours per return.

The original contract has been amended several times to extend the same RIW support to later lots of F-14 production aircraft. In mid-1977 warranty coverage was extended through April 1983.

In addition to the repair activity, the FFW/RIW provided the Navy with additional areas of support:

- Maintenance and overhaul data are being deferred until near the end of the RIW/FFW contract. Several configuration changes accomplished during the FFW/RIW period have had no impact on the Navy logistics system. However, a number of repair parts would have become obsolete by these changes had the Navy been providing support. As it is, provisioning will be accomplished for the latest configuration.
- A rotable pool of 25 ready-for-issue pumps was placed at Abex (the secure storage area concept); Abex can now supply 24-hour turnaround for each pump received. Abex can also respond after receiving a message and need not physically receive a failed item.

Additional information on this procurement appears in References 5-4 and 5-5.

5.3 U.S. AIR FORCE: THE ABEX PUMP

Under Contract F34601-75-C-1695, Abex Corporation is providing an RIW for 28 hydraulic pumps that are being installed on C-130 aircraft. The warranty lasts until all pumps have accumulated an average of 5,000 flying hours or 7 years, whichever occurs first. Exclusions include combat damage and acts of God. A turnaround time of 10 days is allowed for servicing each unit. Should the turnaround time exceed 10 unit-days, the warranty period will be extended by 5 unit-days per unit-day exceeded.

Because of the small quantity purchased under this contract, the RIW appears to be more of a cost-avoidance mechanism than an incentive for reliability improvement. Experience supports this position, since there have only been 6 failures of this item from mid-1975 through mid-1979.

5-4. Markowitz, O., *Aviation Supply Office FFW/RIW Case History #2, Abex Pump,* Proceedings of the 1976 Annual Reliability and Maintainability Symposium, January 1976, IEEE Catalog Number 76 CHO-1044-7RQC, pp. 357-362.

5-5. Markowitz, O., *Abex Corporation, Mid-RIW Contract Evaluation,* AD-A048244, October 15, 1977.

SECTION SIX

RIW PLANS FOR DYNAMIC SYSTEMS

Previous sections have presented the results of our investigation of the characteristics of dynamic systems and the previous applications of warranty and RIW-type requirements to dynamic system procurements. Although there are significant differences between the environments in which avionics RIWs are applied and dynamic systems are procured, the requirements of avionics RIW plans can often be tailored to accommodate these differences. A second approach to applying RIW to dynamic systems is represented by the RAW for the Sikorsky dynamic components on the Blackhawk helicopter. We will refer to this approach as a depot-only RIW (RIW-D).

Section Seven provides a set of RIW application criteria that permits qualitative assessment of the suitability of RIW for a specific program. This section provides guidance in developing appropriate terms and conditions for a dynamic system's RIW. This guidance is generally applicable to both the RIW and the more restrictive RIW-D plan. Information that is specifically applicable to the RIW-D will be identified as such in the text.

Subsection 6.1 addresses the goals of applying RIW and RIW-D to dynamic systems. RIW planning activities during the acquisition cycle are discussed in Subsection 6.2. Subsection 6.3 identifies the major terms and conditions that should be included in an RIW and provides guidance in selecting alternatives appropriate to a specific procurement.

6.1 GOALS OF APPLYING RIW TO DYNAMIC SYSTEMS

RIW terms and conditions similar to those used for avionics equipments can often be tailored to accommodate differences that are present in dynamic system procurements. The entire dynamic system (or subsystem) is covered by the RIW. Portions of the system that would normally be removed from an end item for repair by the DS (or for exchange with GS or depot) are comparable to avionics LRUs and are now sent back to the contractor for repair under RIW. Generally, only preventive maintenance and inspection tasks will be conducted by crew or operator personnel or by organizational-level mechanics. During RIW, the ranges of maintenance tasks at organizational, DS, and GS levels are reduced to a minimum.

As with avionics RIW, the goal of this approach is to give the contractor the greatest possible opportunity to learn from field failures of his equipment, as well as to provide both the incentive and the opportunity for reliability growth, maintenance procedure improvements, and subsequent reduced life-cycle costs.

Under an RIW-D plan, the contractor's maintenance responsibility is limited to those repairs which require depot capabilities. Other maintenance activities (as well as PMI) are accomplished at the appropriate organizational, DS, or GS activity. With RIW-D, non-depot spares, trained maintenance personnel, test equipment, and manuals must be in place at the time of initial equipment deployment.

For items that are depot-repairable only, RIW-D will have the same goals as RIW. As more responsibility for maintenance is transferred to Army organizations under an RIW-D, the contractor's opportunity and incentive to learn about and improve his equipment's reliability and maintainability characteristics are reduced. However, when depot maintenance tasks represent a significant segment of an equipment's repair requirements, or when other reasons (such as high costs of transporting subsystems that are easily repaired at lower levels) make a standard RIW unattractive, the RIW-D can provide an alternative use of the warranty concept.

6.2 RIW PLANNING DURING THE ACQUISITION CYCLE

To maximize the effectiveness of RIW, it is important to consider the concept early in the life of a system's design. In this way, a decision to use RIW has the greatest potential to affect equipment design and production, as well as the planning to maintain and support the warranted items. Figure 4 shows the various phases of an equipment's acquisition cycle, as well as the production and operation phases. The figure also shows the RIW planning associated with each phase. These phases are discussed in the following subsections.

6.2.1 Conceptual Phase

During the conceptual phase, the system is analyzed in very general terms. Background studies may be conducted in terms of reliability, maintainability, and the expected life-cycle cost. RIW (or other cost-control and incentive methods) may be considered in these studies as a means of achieving stated goals and maintaining costs within resource limitations.

6.2.2 Validation Phase

The validation phase begins with a decision that the capabilities of the proposed system are in fact needed; that sufficient engineering has been accomplished to justify continuation of the effort; and that resources should be expended on technical and cost analysis, engineering design, and further system definition. This activity should include consideration of the required reliability levels and their impact on system support. During this phase, it is desirable to identify the basic requirement that RIW

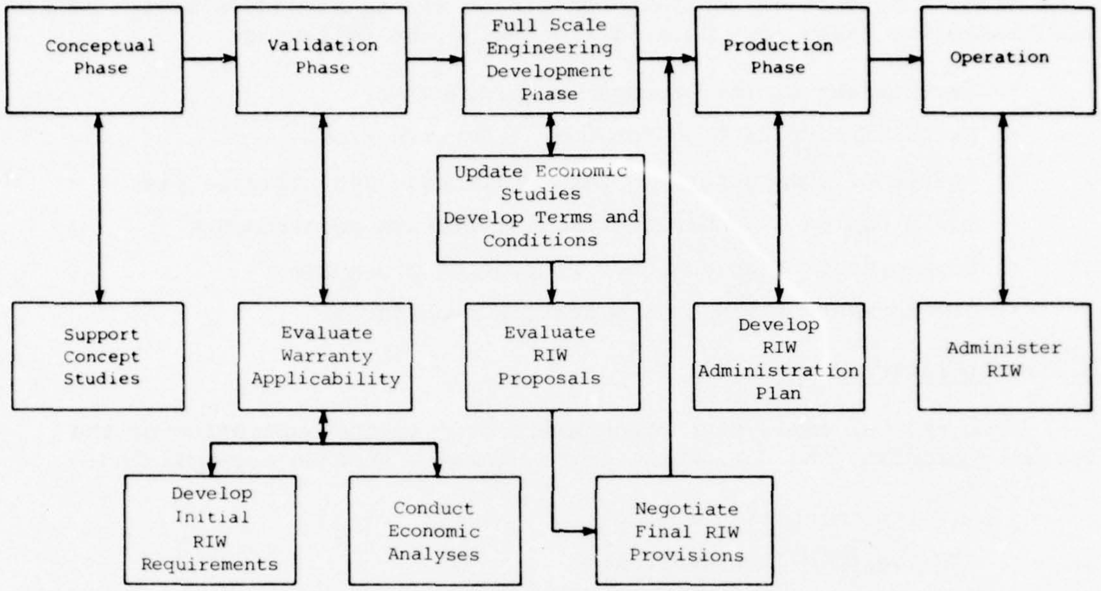

FIGURE 4
RIW PLANNING DURING THE ACQUISITION CYCLE

should satisfy for the future production effort. The trade-offs between RIW and RIW-D should be reviewed to determine if one form of RIW is preferable to the other. Also during this phase it is important (if possible) to communicate to the system developers the intention to consider RIW since this consideration may affect system design. It is recommended that the Request for Proposal (RFP) for the Full Scale Engineering Development (FSED) Phase outline RIW requirements and discuss terms and conditions that may be used in the production contract. Further, the FSED RFP should ask the respondents to discuss their understanding of the requirements and the impact on the FSED effort.

6.2.3 Full Scale Engineering Development

The purpose of the FSED phase is to design, assemble, and test the system and its support requirements to determine if the required operational capability can be achieved within expected or allowable costs. During FSED, better estimates of system reliability and maintenance and support parameters become available. At this time, economic studies can be refined and updated. In preparation for a production decision, the warranty provisions will also be developed to reflect program or equipment modifications that have occurred during FSED. At the end of the FSED phase, the warranty proposals provided by the contractors are evaluated and a final decision is made regarding the intention to use RIW.

6.2.4 Production Phase

After a production contract containing RIW is signed, a series of RIW administrative tasks are required, including the following:

- Development of item management procedures
- Establishment of plan for user indoctrination
- Review of contractor RIW data collection and analysis plan
- Coordination of contractor administrative requirements
- Development of no-cost ECP processing procedures
- Development of RIW implementation procedures

6.2.5 Operation Phase

From initial deployment of an RIW system to the expiration of the warranty program, the following series of tasks must be accomplished:

- RIW implementation monitoring
- RIW logistic flow monitoring
- RIW contract administration
- No-cost ECP review
- Transition planning and implementation

6.3 RIW PROVISIONS

This section addresses provisions that are applicable to the RIW and the RIW-D (introduced earlier in this section). The information is derived primarily from previous corporate studies (e.g., References 6-1, 6-2, and 6-3), lessons learned from various avionics and other applications of warranty and RIW, and the special circumstances observed in Section Three in the comparison of avionics and dynamics systems environments.

The variety of circumstances associated with a specific procurement preclude a rigid approach to developing RIW provisions. Thus this section treats major RIW provisions in general terms, with special attention given to features that could vary depending on the choice of RIW or RIW-D. On

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6-1. Balaban, H.S., and Retterer, B.L., *Guidelines for Application of Warranties to Air Force Electronic Systems*, RADC TR76-32, ARINC Research Corporation, December 1975.

6-2. Kowalski, R., *Lightweight Doppler Navigation System (LDNS) Program*, ARINC Research Publication 1586, April 1977.

6-3. Balaban, H.S., "Reliability Improvement by Profit Incentive," *Quality*, November 1978, pp. 22-28.

the basis of the information in this section, the LDNS RIW (Appendix A) provides specific language that can be used as a baseline for constructing RIW terms and conditions.

RIW provisions can be divided into four areas:

- Statement of contractor warranty
- Contractor obligations
- Government obligations
- Other provisions

The following subsections are discussions of the major features of each area. Data requirements are addressed in Subsection 6.3.5.

6.3.1 Statement of Contractor Warranty

6.3.1.1 Warranty Statement

The warranty statement indicates that the contractor warrants the equipment furnished under the contract to be free from defects in design, material, and workmanship and to operate in its intended environment in accordance with appropriate specifications, drawings, etc., for the warranty period. The warranty statement should specifically identify the system or subsystems covered by the warranty and the quantity of items covered (e.g., all items supplied under the contract).

6.3.1.2 Corrective Action

Under RIW, failed equipment is returned for repair to the contractor's repair facility. A repair verification and test procedure is normally cited in the RIW provisions as a standard for verifying that the failed item has been returned to serviceable condition. This standard is generally not as rigorous or as thorough as the acceptance test procedures used when the item was first delivered to the Government.

For RIW-D, the contractor is responsible only for depot-level repairs. It is important to define further the types of failure, repair, or other conditions that are the contractor's responsibility. In many cases these conditions may be spelled out in the DS or GS manuals; if they are, the DS or GS manuals should be referenced in the provisions.

6.3.1.3 Warranty Coverage Period

In existing RIW contracts, the period of coverage is often stated in terms of calendar time, operating hours, or a combination of these parameters. The best way to define a period of coverage will depend upon the application at hand. RIW coverage normally begins at the time of Government

acceptance. In defining the period of coverage for dynamic systems, the following factors must be considered:

- Installation or Deployment Schedule - Occasionally, equipment will be put into operation shortly after Government acceptance. If this is not the case for a particular procurement, then the warranty period could be extended to some time after "first substantial use" or, more specifically, some time after "deployment of the Nth item".
- Operating Rate - For equipments that operate on a shift basis or a regular number of hours per month (as avionics equipments tend to be used), it may be possible to define a total number of operating hours (or maximum time interval) as the period of coverage. Then estimates of actual total usage can be made on the basis of either field surveys or usage rates observed from failed and other returned units. For items with irregular or unpredictable usage rates, it may be more appropriate to cover each item for "X operating hours" or "Y years", whichever occurs first.

In each case, the objective is to give the contractor a picture of the expected usage under RIW. Then the contractor is better able to identify the resource commitment that must be made and thus better able to price his warranty commitment.

6.3.1.4 Exclusions

Failures that result from circumstances outside the contractor's control are normally excluded from warranty coverage. Examples are fire, lightning, flood, and explosion. In addition, under RIW-D unauthorized or improper maintenance at organizational, DS, or GS levels could be grounds for exclusion. To preclude unauthorized maintenance, seals are usually installed on warranted items. Seal breakage, coupled with other evidence of unauthorized maintenance, could be cause for exclusion from warranty coverage, and the item would be repaired under a separate repair agreement. For both RIW and RIW-D, lack of, or improper performance of, PMI tasks might also be reasonable cause for exclusion. Each of these situations must be spelled out in the RIW provisions.

Normally the Defense Contract Administration Service (DCAS) Organization or a counterpart activity at the contractor's plant reviews a contractor's claim that a specific return should be excluded from repair under warranty. Repair of these items is then accomplished under a separate repair agreement and paid for with non-RIW funds.

6.3.2 Contractor Obligations

6.3.2.1 Engineering Change Proposals (ECPs)

By directly observing all field failed items and being responsible for repairs, the contractor has the opportunity to quickly identify failure patterns and institute appropriate corrective action through ECPs (which,

by the terms of the warranty, are introduced at no cost to the Government). Class 1 ECPs will generally follow MIL-STD-480 procedures necessary for configuration control. Such ECPs should be encouraged under the terms of the RIW. Later, in the subsection on Government Obligations (Subsection 6.3.3), we will examine the commitment that the Government might make in this area. Changes not affecting form, fit, and function can be immediately introduced into a production line and into the repair activity with proper notification to the resident Government representative. To assure a standard configuration at warranty expiration, the contractor can be required to incorporate all such no-cost ECPs into new production units and all returned units and to provide modification kits for the remaining unmodified units. If the warranty period is long enough to result in multiple returns of each unit, the number of unmodified units at warranty expiration will probably be small. Otherwise, it may be advisable to require a schedule of prices for modification kits that is effective at warranty expiration so that the Army can bring the population up to the latest configuration.

6.3.2.2 Warranty Markings and Seals

The contractor is obligated to provide suitable labels on warranted units to indicate warranty coverage. When the warranty period does not start until after deployment or installation, a final warranty label may be affixed in the field. If the Government installs warranted items in other systems, the contractor may provide the warranty markings and seals that are normally affixed as part of the installation process.

If the label design must allow room for entering specific data during each installation or removal, this requirement should be included in the labeling provision.

The contractor is also required to provide appropriate seals for warranted equipment to discourage unauthorized maintenance. This requirement should also be included in the contract provision for markings and seals.

6.3.2.3 Secure Storage Area

Requirements for the establishment and operation of a secure storage area should be identified. Normally, the secure storage area is collocated with the RIW repair facility and the Government keeps its own assets there, using the secure storage area as it would a depot. Repaired units are placed in the secure storage area as their repairs are completed and verified. Units are removed from secure storage and sent to requesting units when specified types of messages are received at the contractor's facility. Generally, shipments from secure storage follow a first-in, first-out (FIFO) priority to ensure rotation of assets. Methods of shipment and a maximum response time are also specified in the secure-storage-area provision.

6.3.2.4 Unverified Failures

Under both RIW and RIW-D, it is expected that some of the units removed by Army personnel will "retest OK" (RTOK) when received at the contractor's repair facility. Because of the cost incurred by the contractor in processing these unverified failures, the warranty provisions normally specify a maximum number (either per calendar period or as a percent of total units returned) that the contractor is obligated to process without additional reimbursement. Values between 10 and 30 percent of total units received are normally cited for electronic units that will be processed without reimbursement. When the maximum number of unverified failures is exceeded, the provisions will include a dollar-amount reimbursement to be paid to the contractor for handling and processing each unit returned above the maximum number allowed.

6.3.2.5 Turnaround-Time Requirements

It is necessary to establish either a maximum or average number of days for the contractor to accomplish repair and make a failed unit available for use. This assures that GS organizations have an adequate stock on hand to support demands. Ideally, turnaround time encompasses the period from receipt of a failed item at the repair facility shipping dock to the time the item has been repaired, the repair verified, and the item placed in the secure storage area. Turnaround time for avionics typically runs from 15 to 35 calendar days. For a given RIW on a dynamic system, it might be necessary to establish an individual turnaround time for each LRU associated with the system because of test complexity, teardown or assembly procedures, etc.

As long as assets are available from the secure storage area when demands arise, the contractor's compliance with turnaround-time requirements is not critical to the maintenance of materiel flow under RIW. When demands cannot be met from secure storage and a contractor is not in compliance with turnaround-time requirements, some form of remedy is identified in the RIW provisions. Remedies that have been used include:

- Requiring the contractor to provide spare items at no cost to the Government on the basis of a specified formula
- Extending the time of warranty coverage for the entire population or for items not repaired in the specified period
- Establishing a monetary penalty on the basis of a specified formula

The LDNS provisions in Appendix A use the third approach. Of these alternatives, the first provides the most support to the using organizations, since it directly addresses the objective of having sufficient spares to maintain a pipeline. However, if the contractor no longer has the units in production, this requirement may not be feasible (except at high RIW cost or risk to the contractor). The latter two plans are considered alternatives to the first one. While they are not a substitute for additional spares, they do provide the contractor with an incentive to meet the turnaround time when necessary.

6.3.3 Government Obligations

The Government obligations under RIW should be spelled out in this part of the provision. They include the following:

- Accomplishing PMI in accordance with the applicable technical orders. For RIW-D the Government must also accomplish certain repair activity in accordance with appropriate technical orders. Failure to comply with these requirements could be cause for exclusion.
- Providing expeditious processing of no-cost ECPs submitted in response to the RIW. To stress its commitment to this goal, the Government will often allow these ECPs to be automatically approved 30 or 35 days after submission, unless specifically disapproved during that period.
- Testing all suspected failures in accordance with applicable technical orders to verify that the units have in fact failed.
- Furnishing test readings and failure circumstance data to the contractor, together with the failed unit.
- Providing installation, removal, and operating time data on RIW labels affixed to the warranted items.
- Shipping units as failures occur to minimize batching.
- Providing Government representatives at the contractor's repair facility to verify data requirements, exclusions, RTOKs, and completion of corrective actions.

The provisions may indicate that even if the last five items listed above are not met, the contractor is still responsible for making repairs under the RIW.

6.3.4 Other Provisions

The final section of the contract provision addresses features of RIW that do not conveniently fit in the previous sections. These features can include:

- A procedure for contractors to use to establish claims of exclusion
- A procedure for disposition of excluded units not considered by the Government to be economically repairable
- Specific formulas or methods for estimating operating hours, turnaround time, or other parameters necessary to administer RIW

This section may also describe conditions, if any, under which RIW price adjustments are made. Such price adjustments could be necessitated by the following:

- Units lost or damaged beyond repair. In the event a warranted unit is no longer repairable, an equitable adjustment can be made in the

contract price, especially if such units amount to more than a specified percentage of the total population.

- Operating time adjustment. If the warranty coverage (and thus contractor exposure) is based on operating time per calendar period, provisions can be made for adjusting the contract price for deviations from this pricing standard. To minimize adjustments caused by small variations, a range (such as ± 10 percent) is often established within which no adjustment is made.

- Unverified failures. If the provisions specify a percentage of the total returns that the contractor will process without a price adjustment, the negotiated cost per unit for processing returns above the stated value is used to adjust for higher-than-expected rates of unverified failures.

The warranty provisions should indicate which of the above adjustments are applicable, the procedures by which adjustments will be made, and the dates on which adjustments will be effected.

6.3.5 Data

Under RIW, the contractor is required to develop a data system capable of processing information collected during the RIW program and producing specific reports. The three data items generally associated with the RIW are described in the following subsections. The DD Form 1423 and supplemental instructions for these RIW data items for the LDNS appear in Appendix B.

6.3.5.1 Data Collection and Analysis Plan

The Data Collection and Analysis Plan should be submitted as soon as possible following production contract award. It describes the records that the contractor will keep, the procedures for converting these records into RIW information, and the formats to be used in reporting on RIW. This data item also identifies Government contributions to the RIW data. It must be thoroughly reviewed because it forms the foundation for subsequent assessment of the RIW program, defines the Government's participation in the data effort, and identifies the procedures used to calculate RIW-related parameters (including contract adjustments).

6.3.5.2 Warranty Data Report

The Warranty Data Report is issued periodically throughout the warranty period; it summarizes warranty claim and report activities for each report period. The calculations used to develop the information in the report and the formats used to display the resulting information should conform to those described in the Data Collection and Analysis Plan. This report will assist in identifying the status of RIW implementation (e.g., missing or incomplete data) and in planning for transition (by identifying failure frequencies, failure modes, etc.).

6.3.5.3 Warranty Effectiveness Study

The Warranty Effectiveness Study provides a formal opportunity to the contractor to discuss RIW experience under this contract and to provide recommendations and suggestions on ways to improve the administration and implementation of future RIW procurements.

6.4 PROPOSAL EVALUATION

RIW will usually be an evaluation area when a production RFP contains RIW provisions. The RFP instructions will require each offeror to present an approach to meeting RIW requirements. Usually two cautions are stated:

- Do not offer simply to conduct a program in accordance with RFP requirements
- Address each and every RIW provision

Table 7 lists factors and evaluation criteria that provide guidelines for evaluating an offerer's RIW proposal. These criteria also assist in identifying areas that require clarification. This table must be interpreted to reflect the specific requirements of each solicitation.

TABLE 7
RIW EVALUATION FACTORS AND CRITERIA

Warranty Management - The offeror's overall approach to managing and staffing the warranty program is clearly stated.	The organization or group responsible for managing the warranty should be clearly defined. It should be demonstrated that this organization can perform the necessary warranty functions, including the liaison between the warranty repair group and design, reliability, quality-control groups and higher management levels within the organization. The offeror's overall approach should demonstrate an understanding of both the general goals of the RIW and specific requirements.
Facilities and Equipment - The existence, adequacy, and availability of resources necessary for executing warranty responsibilities are identified.	The existing or planned facilities for performing warranty services should be fully described and demonstrated to be suitable. These include the repair facility and storage, receiving, and shipping areas.
Warranty Data - The offeror can comply with the data requirements of the RIW.	The offeror's approach to developing and maintaining a data system should be appropriate for meeting warranty data collection and analysis requirements in a timely and complete manner. Specific attention should be directed toward his treatment of critical parameters involving contractual commitments such as turnaround time and equipment modification status.

(continued)

TABLE 7 (continued)	
In-Plant Materiel Flow - The offeror's approach to processing warranty returns and exclusions and meeting specified turnaround times is identified.	The procedures by which the offeror will receive, test, repair, modify, store, and ship the warranted equipment should be fully described and should be consistent with the RIW terms and conditions. Specific attention should be given the offeror's understanding of exclusions and the definition of unverified failure. The offeror should describe the time sequence of material flow, with accompanying rationale, to show that specified turnaround times can be achieved.
Government Obligations - The offeror's understanding of Government obligations under RIW is clearly stated.	The offeror should identify allowed Government maintenance and PMI activity under RIW as well as any allowable repair activity under RIW-D. Restrictions on Government flexibility with respect to replacement items, manpower assignments, etc., must be clearly stated. Access required to Government maintenance records must also be addressed.
DCAS Interface - The offeror's approach to interfacing with DCAS is considered.	The offeror should describe when and how he will interface with DCAS. He should be explicit as to the responsibility of DCAS under RIW.

SECTION SEVEN

RIW APPLICATION CRITERIA

7.1 INTRODUCTION

The decision to incorporate RIW in a solicitation must not be made lightly. The development of meaningful, effective, and enforceable provisions will require significant Government effort. Offerors must understand their responsibilities under RIW, and must be prepared to estimate the dollar cost of these responsibilities. At the same time, the program office responsible for the procurement will have to coordinate RIW contracing activity with appropriate administrative, maintenance, supply, and logistics activities. While all of these tasks are normally required during the procurement process, it must be realized that dynamic components represent a relatively new area of application for RIW and that the applications will therefore require special attention until some history and lessons learned are developed.

Earlier sections presented the origins and use of the RIW for avionics, the principal differences between the avionics and dynamic systems environments (with special attention to procurements at MERADCOM), and some background on previous applications of warranty to dynamic systems. This section is intended to assist potential RIW users in determining whether or not the concept is likely to offer benefits for a specific procurement. It presents a set of RIW application criteria that are based on avionics RIW criteria but also address the major differences observed between avionics and dynamic systems environments. These differences have been included in the criteria either through the addition of new criterions or through the presentation of rationale specifically related to dynamic systems. These new criteria permit qualitative assessment of the suitability of RIW for a specific program. If a program meets these criteria, a more detailed analysis of administrative and economic factors should be undertaken to assess the specific benefits to be derived from RIW and to make a decision on whether or not to incorporate RIW into the program. If a decision is made to proceed with RIW, the criteria can also be used to identify areas that need special attention.

7.2 RIW APPLICATION CRITERIA FOR DYNAMIC SYSTEMS

Table 8 presents a number of RIW application criteria that can be used to assess the suitability of RIW for the acquisition of a specific dynamic system.

TABLE 8
RIW APPLICATION CRITERIA FOR DYNAMIC COMPONENTS

Criterion	Rationale	Significance*	
		RIW	RIW-D
	Procurement		
The procurement will be on a fixed-price basis.	Under current DAR provisions, contractor warranty expenses are admissible under a cost-type contract. A cost-type arrangement could significantly reduce a contractor's incentive under RIW. RIW price could be firm fixed-price or could be negotiated in terms of target and ceiling costs and sharing ratios.	1	1
Multiyear funding is available for RIW.	The RIW period should be long enough to provide the contractor with an incentive to achieve reliability goals rather than simply bear the increased cost of repairs if goals are not met. The period should be long enough to provide the contractor with an opportunity to benefit from any no-cost ECPs that he can develop. Sufficient funds to cover this interval must be budgeted and available at the time of the procurement.	1	1
The procurement is competitive.	Competition among offerors can promote a greater interest in understanding RIW responsibilities and analyzing risk factors before developing a bid price. Without competition, there could be a tendency simply to add a contingency cost to cover a perceived risk.	1	1
The RIW equipment design has been developed or controlled by the offeror.	When a procurement requires an offeror to build to Government-supplied drawings or to use Government-specified components, there may be limits on the enforceability of any additional responsibilities, such as RIW, included in the contract. The DAR, Paragraph 1.324, part 2, suggests that in these cases the contractor could be limited to remedying defects in material and workmanship or failure to conform to specifications. Although RIW is not prohibited in these cases, the requirements for the RIW will have to be very carefully established.	1	1
Potential offerors have proven capability and experience in supporting equipment.	Capability and experience in supporting similar items can provide offerors with a data base for realistic pricing of RIW responsibilities.	2	2

*1-Major; 2-Secondary; 3-Minor.

(continued)

TABLE 8
(continued)

Criterion	Rationale	Significance*	
		RIW	RIW-D
	Procurement (continued)		
Production/deployment/ usage schedules support the RIW goals and requirements.	A desirable feature of RIW is the opportunity for an offeror to learn about his equipment through the experience of repairing failed units. RIW costs may be reduced if some repairs can be interleaved with production activity. No-cost ECPs may be introduced more quickly (and at less expense) when a production line is running. In general, the more production/deployment/ usage schedules promote feedback and coordination of RIW activity, the greater the offeror's opportunity to meet RIW goals.	2	2
The RIW can be efficiently planned and administered.	The success of an RIW effort depends on the ability of the Government and contractor to jointly fulfill their responsibilities under RIW. For the Government, this will require a plan for administering RIW that addresses material flow, record-keeping and reporting during the life of the RIW. It is important to be able to identify as early as possible cognizant agency responsibilities and applicable procedures.	2	2
	Equipment		
The maturity of equipment reliability is at an appropriate level.	RIW would not be appropriate for items that are (1) state-of-the-art or high technology designs with little or no commercial or military experience, or (2) very mature in design and offer little or no opportunity for growth or improvement after production. In the first case, the offeror may be subjected to extreme cost risks under RIW. In the second case, standard production and qualification acceptance tests may be sufficient to confirm that the equipment meets reliability requirements. RIW incentives are intended for use on designs that can benefit from reporting of field results to the contractor. Service contracts or other support arrangements would be more appropriate for the cases described above.	1	1
Item can be marked or labeled to show existence of RIW coverage.	Suitable markings or labels provide an effective means of communicating the existence of RIW to user and maintenance personnel. These markings can prevent or reduce the frequency of unauthorized maintenance and hence the number of exclusions that will occur under RIW. Special attention in this area is needed for items that cannot be marked or labeled because of their physical size (too small) or shape (highly irregular).	2	3

*1-Major; 2-Secondary; 3-Minor.

(continued)

TABLE 8 (continued)			
Criterion	Rationale	Significance*	
		RIW	RIW-D
Equipment (continued)			
Item operational reliability and maintainability are predictable.	Reliability estimates are important for determining the expected number of failures; maintainability estimates are important for determining expected repair costs. Too much uncertainty in such estimates may expose the contractor to undue risks. Designs containing a significant quantity of new part types for which there is no method of predicting reliability may not be good candidates for RIW coverage.	1	1
The RIW item operates independently of other systems.	When the performance of an item under RIW is highly dependent on or integrated with the performance of one or more items not covered under the same RIW, it may be difficult to determine which item is at fault when a failure occurs. As a result, the contractor may be repairing failures not under his control or the Government may pay for repair of exclusions that should be covered under the RIW.	2	2
The item has a modular design to simplify fault isolation and repair activity.	If extensive field or DS activity is required to fault-isolate to the level at which RIW is applied, the incremental cost to make the repair may be far lower than the cost of moving the item back to a contractor. On the other hand, if the equipment is designed for rapid fault isolation to the level at which RIW is applied, RIW costs may compare more favorably with the incremental repair costs.	2	3
An elapsed-time indicator (ETI) can be installed on the item, or other methods are available to provide usage data to the contractor.	ETIs permit accurate measurement of operating time, thereby permitting more complete assessment of usage, failure rates, and trends.	3	3
Operations			
Use environment is known or predictable.	The contractor must evaluate and price his responsibilities and risks under RIW. Information on the expected use environment, including operating rates, must be available to him. Such information is also required by the contracting agency to permit independent evaluation of price. If operating rates are not available, RIW coverage could be defined to extend over the first X operating hours of each delivered item.	1	1

*1-Major; 2-Secondary; 3-Minor.

(continued)

TABLE 8
(continued)

Criterion	Rationale	Significance*	
		RIW	RIW-D
Operations (continued)			
Item wartime or peacetime mission criticality is not affected by RIW.	Any reduced self-sufficiency associated with RIW (e.g., reduced in-service maintenance capability or a need to spare at LRU level during RIW) must be tolerable. In many cases, contractor activity under RIW provides greater asset visibility and asset-management flexibility than normally available.	1	3
Operational failure and usage data can be supplied to the contractor.	In order to identify failure modes or conditions of failure, and to estimate failure-mode frequencies, this information should be supplied to the contractor as expeditiously as possible. Otherwise, his ability to understand the item's operating characteristics is severely reduced, as are his chances of meeting the intent of the RIW commitment.	2	2
Sufficient data will be available to compute or estimate MTBF or other reliability parameters.	This information is not strictly required to implement RIW. However, the intensive asset management effort associated with RIW provides an excellent opportunity to develop operational estimates of reliability not generally available from other sources.	3	3
Support			
There is little opportunity to induce failures during Preventive Maintenance and Inspection (PMI) activity. Failures are not likely to be induced if PMI is not performed as required.	Extensive PMI activity is associated with many dynamic systems or with systems they interact with. If improper PMI actions or nonperformance of PMI can induce failures in the RIW items, the necessary repairs are likely candidates for exclusion under RIW. This class of failures will have to be funded in addition to the RIW cost. Under these circumstances, the contractor's incentive under RIW is reduced.	1	1

*1-Major; 2-Secondary; 3-Minor.

(continued)

TABLE 8
(continued)

Criterion	Rationale	Significance*	
		RIW	RIW-D
	Support (continued)		
Contractor can verify performance of PMI.	When PMI activity is an essential part of the maintenance activity for an RIW item, it may be useful for a contractor to be able to review PMI activity in order to identify failure modes or to determine that existing PMI procedures are adequate. It would be useful for the offerors to know what form the PMI records have, where the records are maintained, and for what interval they might be reviewed.	2	2
Unauthorized maintenance can be controlled.	Items whose construction precludes the installation of seals or other control mechanisms to prevent unauthorized maintenance are considered poor candidates for RIW unless careful maintenance-technical discipline can be exercised. Failure to achieve discipline in maintenance will tend to result in excluded repairs that will have to be funded outside the RIW.	2	2
Item is *field*-testable without extensive disassembly.	If field test equipment and procedures allow isolation to the RIW item without extensive disassembly, it may be economical to return the item to the contractor for repair. On the other hand, if the incremental effort to make an in-service repair is small once fault isolation is accomplished, the RIW can be especially well suited to systems that are normally GS or depot-repairable.	2	3
User and maintenance organizations have appropriate transportation and packaging capabilities to support RIW.	RIW can affect transportation and packaging needs by requiring a capability to ship assemblies or subassemblies back to a contractor where otherwise only failed parts might be sent to a GS or depot. If this requirement creates problems for the user or DS levels, other support alternatives should be considered.	1	3
	Economics		
The contract provides sufficient opportunity for a contractor to identify and develop R and M improvements.	If deployment schedule and usage rate will not generate sufficient failure or maintenance actions over the RIW period, the contractor will have little opportunity or motivation to improve the reliability or maintenance characteristics of his equipment.	1	1
The contractor has the opportunity, with reasonable risk, to make a profit on the RIW line item in the contract.	Since RIW is procured at a fixed price, the basic variables that influence this price must be known or the contract should contain appropriate adjustment clauses to compensate for differences that occur outside the contractor's control.	1	1

*1-Major; 2-Secondary; 3-Minor.

The criteria are divided into five areas: procurement, equipment, operations, support, and economics. For each criterion a rationale is presented that explains, as succinctly as possible, the importance, impact, and implications of the criterion. Two types of RIW are addressed in the table. The RIW column represents the avionics type of RIW, under which the contractor assumes major responsibilities for all maintenance during the warranty period. The RIW-D column represents a warranty under which the contractor is responsible only for depot-level repairs during the warranty period.

In the body of the table, each criterion has been assigned a significance factor which assesses the relative importance of that criterion to each RIW plan. These factors are interpreted as follows:

1. Major - Failure to meet the criterion could be grounds for rejecting RIW or at least requires a reassessment of the goals of, or implementation methods for, the RIW.
2. Secondary - Failure to meet the criterion would generally not be grounds for rejecting RIW. However, this factor should be given special attention in the development of an RIW plan. The cumulative effects of several secondary grades for a program or equipment could be cause for rejecting the use of RIW.
3. Minor - Failure to meet one or more of these criteria is generally not cause for rejecting RIW. However, special consideration should be given to these factors in the structuring of the RIW.

The following subsections describe the criteria areas that appear in Table 8.

7.2.1 Procurement

The circumstances under which the RIW is procured will affect RIW applicability. Although these criteria have almost equal impact for RIW and RIW-D, they help to determine if the procurement circumstances are consistent with RIW needs.

7.2.2 Equipment

Equipment criteria examine the basic design features of the equipment being procured. In many cases these features are under the control of the development contractor or offeror and may differ among offerors.

7.2.3 Operations

Operations criteria examine the anticipated operational use of the equipment. Responses to most of these criteria are established by Government requirements, although some contractor influences are also present. For example, in the case of the ability to estimate operational R&M characteristics, the Government may have historical data on similar classes

of equipment or field performance data for similar technology devices, while individual offerors may have either a wide variety of or no military field experience in the type of equipment being warranted.

7.2.4 Support

Support criteria examine aspects of equipment support that are not specifically performance-related. They cover a mix of Government- (especially the user) and offeror-controlled features of the equipment.

7.2.5 Economics

Unless sufficient failure and maintenance activity is anticipated for the equipment, the opportunity and motivation for improving reliability or repair characteristics of the equipment are diminished. The RIW is then reduced to a complex contract for services that might be obtained more economically in other ways.

In addition, unless the RIW line item presents an opportunity to the offeror to make a profit at a reasonable risk, the use of RIW must be strongly questioned.

7.3 USE OF APPLICATION CRITERIA

Table 8 was designed to be used by an analyst who has an understanding of the goals and concepts associated with RIW, as well as the program office's requirements for the procurement. With such understanding, the user of this table can determine the relative importance or applicability of each criterion for an intended application.

When a specific program is reviewed against these criteria, several types of response can be expected. For some criteria (e.g., the procurement is competitive) a simple yes or no may be possible. For other criteria, (e.g., unauthorized maintenance can be controlled) the response will be less specific. In some cases (e.g., the item operates independently of other subsystems) the response may vary among offerors. Finally, some criteria (e.g., known or predictable use environment) may require analysis or review of requirements before any answer can be developed.

When this review is completed, a program office should have the basic information required to answer the following questions:

- What are the principal risks (unknowns) facing an offeror who will bid on RIW? How can these risks be reduced?
- What other principal concerns must be addressed in the development of RIW terms and conditions? How can risks in these area be reduced?
- Are the potential benefits of RIW available in this procurement, or would other incentive or support concepts be more appropriate?

Once these questions are answered, a decision can be made whether or not to proceed with a detailed analysis of economic factors, development of terms and conditions, and planning for RIW administration.

SECTION EIGHT

ECONOMIC EVALUATION OF RIW

Section Seven presented qualitative factors to be considered in deciding how or when to apply RIW to dynamic systems. This section examines the economic analysis that can be performed to determine the financial feasibility of an RIW program. The economic evaluation consists of establishing the difference between the expected life-cycle cost under RIW and the expected cost if the system is supported under normal organic maintenance. A previously developed RIW cost model, modified for use with dynamic systems, is used to perform the economic comparison. The modifications include the addition of three cost categories relevant to dynamic systems but not generally considered in previous RIW analyses: preventive maintenance, overhaul/refurbishment, and fuel/energy costs. In addition, where previous models often allowed for reliability growth with increased use, modifications were made to allow for "negative growth", or "reliability decay", which represents a wearout process.

Subsection 8.1 addresses the need for and types of economic analysis applicable at each program phase; Subsection 8.2 presents the RIW economic analysis methodology; and Subsection 8.3 describes the inputs and outputs of the dynamic system RIW LCC model.

8.1 ECONOMIC ANALYSIS DURING THE ACQUISITION CYCLE

Economic analysis of RIW can be performed at several points in a system's life cycle. Table 9 summarizes the principal points of application.

8.1.1 Validation/Full-Scale Engineering Development

Although RIW is part of a production contract, planning for the use of the concept should begin as early as possible in the validation or full-scale engineering development phases. At that time, the basic economic feasibility of RIW can be determined. Typically, during these early phases, economic analysis can determine the effect of various terms and conditions on the various levels of RIW. These analyses will complement discussions with the development contractors, which may accompany the development of terms and conditions (see Figure 4).

TABLE 9 ECONOMIC ANALYSES RELATED TO USE OF RIW	
Life-Cycle Phase	Purpose of Economic Analysis
Validation/Full Scale Engineering Development	• Determine Economic Feasibility of RIW • Evaluate Various Maintenance Concepts and RIW Plans • Evaluate Sensitivity to Terms and Conditions
Source Selection	• Evaluate Economic Advantage of RIW • Provide Inputs to Source Selection
Post-Production	• Evaluate Modifications to Original Warranty Program • Evaluate Transition Strategies

8.1.2 Production Source Selection

Since RIW applies to production units, the decision to obtain an RIW will be made as part of the production source selection. The basic decision is concerned with determining if the RIW price offered by the contractor meets the economic interests of the Government. In other words, the cost of RIW must be compared with the expected benefits that such a cost represents.

During source selection for the production award, the decision to use RIW requires that many factors in addition to economics be considered. Unfortunately, there is no precise formula available to aid in making this decision. If the application criteria in Section 7 raise no obstacles and if there is a potential cost advantage for RIW, a positive decision would be reasonable. Conversely, the failure to meet several of the Section 7 criteria, together with analyses that indicate a cost disadvantage for RIW, would reasonably lead to a negative decision. Cases that fall in between these extremes will require careful weighing of the merits of RIW versus other support and incentive alternatives. In any case, it is necessary to consider the accuracy of the input data and to examine the sensitivity of cost differences to changes in input parameters.

8.1.3 Post-Production Award

After award of a production contract that includes RIW, economic analyses may be performed to evaluate possible changes in the warranty program. For example, additional uses of the equipment may be identified, another service may decide that the equipment will meet its requirements, or the equipment may become a candidate for foreign military sales. An analysis may also be needed to determine the changes in the economic benefits of RIW due to revised operational usage.

Finally, as repair experience is accumulated under RIW, economic analyses may be used to develop and plan maintenance and support transition activities.

8.2 ECONOMIC ANALYSIS METHODOLOGY

Figure 5 presents an overview of the methodology used for economic analysis of RIW. Although we will discuss the specific LCC model used in this investigation, the basic features of this methodology would apply to any applicable cost-estimating technique.

8.2.1 Develop Baseline Data

Step 1 in Figure 5 requires an analyst to compile baseline data pertinent to the problem. Often, specific data requirements are defined by the model used in the analysis. As indicated in Figure 5, the LCC model used in this investigation requires two data files: a General Data File, which contains data regarding deployment, maintenance scenario, and various cost and labor factors; and an Equipment Data File, which contains specific design and packaging data. With this structure, the analysis of alternate designs generally requires only changes in the Equipment Data File, while analysis of different procurement and deployment scenarios generally requires changes in the General Data File.

8.2.2 Develop Point Estimate

Step 2 in Figure 5 represents the effort required to develop a point estimate of LCC differences between RIW and organic alternatives. These differences will be computed by using the baseline data. For our specific LCC program, this computation requires the analyst to use a computer to read the input data files; to identify to the specific program the types and amount of output desired (initialize model); and, after the calculations have been completed and printed, to review the program outputs.

8.2.3 Conduct Sensitivity Analysis

Step 3 requires the analyst to examine the sensitivity of baseline results to changes in the input data. It is especially useful to test sensitivity to parameters that are not well known (e.g., certain pipeline times), or that could vary in field use (e.g., MTBF).

8.2.4 Document Analysis

At step 4, the analyst will have baseline results and sensitivity results for critical parameters. This information will form the basis of an economic review of RIW.

8.3 LCC MODEL FOR ECONOMIC ANALYSIS OF RIW

The LCC model developed for this investigation is an adaptation of models developed by ARINC Research Corporation for the analysis of Air Force avionics

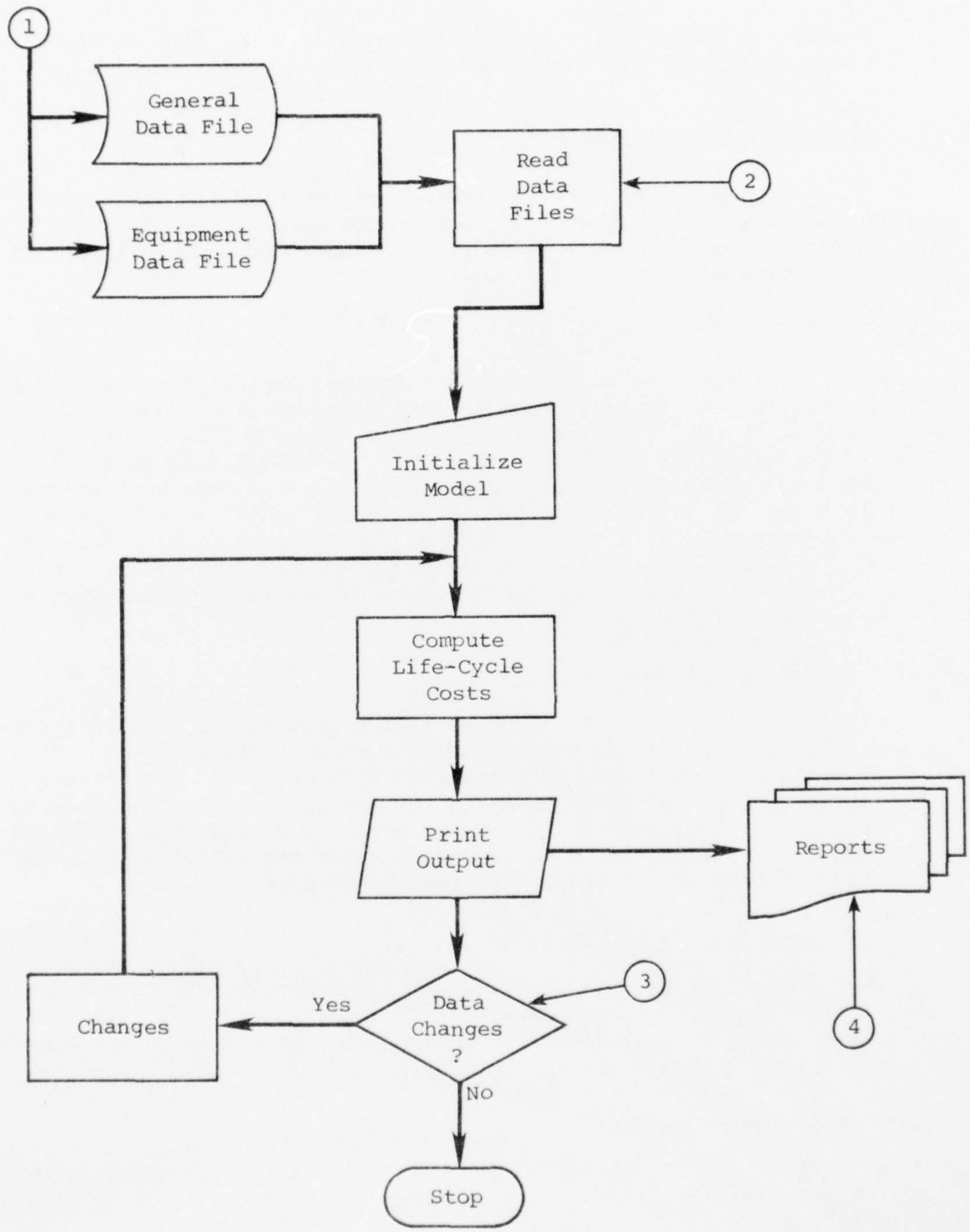

FIGURE 5
RIW ECONOMIC ANALYSIS METHODOLOGY

and ground electronics systems. The model permits comparisons of the LCC of a procurement with RIW and with organic maintennace. The life-cycle costs of individual support strategies are not complete LCC estimates, since they will generally exclude cost elements that are the same or only slightly different between alternatives.

8.3.1 Objective of the Model Development Effort

The principal objective in developing this model is to permit an analyst to identify the potential economic benefits of RIW for a specific procurement, without extensive data inputs. For this reason, many inputs are averages over an equipment or averages across all User, Direct Support, or General Support activity. Thus the model has sufficient detail to identify (in a general sense) potential RIW benefits (on the lack thereof) and the cost categories where these benefits may be found. If more detailed analysis are required, other models must be found that will permit finer gradations in the analysis.

Table 10 presents the cost categories that appear in the model. These cost categories will be discussed further in Subsection 8.3.3. As noted in Table 10, three cost categories have been added to earlier RIW LCC models to reflect the potential requirements of dynamic systems: Preventive Maintenance, Energy/Fuel, and Overhaul/Refurbishment.

TABLE 10
COST CATEGORIES FOR ECONOMIC ANALYSIS OF RIW

Acquisition
Initial Spares
Replenishment Spares
Corrective Maintenance
Preventive Maintenance*
Warranty Price
AGE
Energy/Fuel*
Overhaul/Refurbishment*
Data
Inventory Management
Other Costs

*Added for dynamic systems.

8.3.2 Model Inputs

For the LCC model used herein, two data files must be developed:

- A General Data File, which contains information describing the organic and RIW maintenance concepts, pipeline times for the logistics cycles being analyzed, average labor rates for contractor and Government personnel, expected reliability growth (or decay) rates under warranty and organic support, deployment schedules, average usage rates, and other similar factors.
- An Equipment Data File, which contains data more directly related to equipment design and packaging. This file includes a system hardware description that identifies the equipment being warranted, the subassemblies within the equipment, and the modules within each subassembly. Various cost, reliability, and maintainability data are required at each level of equipment description. At the equipment level, data requirements include overhaul/refurbishment rates and energy/fuel costs (as applicable).

Details on the contents and formats of these data files and specific definition of data involved are presented in Appendix D.

8.3.3 Model Outputs

There are two principal outputs of the RIW LCC model: the point estimate, broken down by cost category; and the sensitivity-to-warranty-period analysis. Together, these outputs can be used to analyze a specific procurement.

8.3.3.1 Point Estimate

Table 11 shows for a particular set of inputs the LCC for ten years of organic maintenance and the LCC for four years of RIW (followed by six years of organic maintenance). (A ten-year useful life was a model input.) The two lead lines in the table show the estimated warranty price for four years and the cost of warranty in terms of the acquisition cost of the equipment. The latter figure is expressed as "Percent per Year per Installed Set", which is calculated from the formula:

$$\frac{\text{Total Warranty Price} \times 100}{\text{(Number of Years of Warranty) (Hardware Acquisition Cost)}}$$

The cost categories in Table 11 are those shown in Table 10; these costs are defined below. Appendix D provides additional details on the methodology used to calculate each cost category.

Acquisition

Acquisition costs include the costs of the equipment to be installed (or deployed), but not the cost of spares. The acquisition costs may be the same for both warranty and organic, but this is not necessary.

TABLE 11
RIW LCC POINT ESTIMATE

4.0 YEAR WARRANTY PRICE 163981.
PCT/YR PER INSTALLED SET 1.21

	ORGANIC	WRNTY/ORG
ACQUISITION	3400000.	3400000.
INITIAL SPARING	104000.	102098.
REPLENISHMENT SPARES	0.	0.
CORRECTIVE MAINTENANCE	264447.	214438.
PREVENTIVE MAINTENANCE	365716.	365716.
WARRANTY PRICE		163981.
AGE	235000.	185867.
ENERGY	2151270.	2151270.
OVERHAUL	320139.	320139.
DATA	50000.	37321.
INVENTORY MANAGEMENT	386669.	197167.
OTHER	0.	27321.
TOTAL	7277240.	7165316.

Initial Sparing

The initial sparing category includes the cost of recoverable spares required for support of the installed items. With respect to life-cycle cost, it is necessary to consider the spares cost associated with transition from warranty to organic maintenance. Generally, at the time of transition, there will be an excess of spare subassemblies since these subassemblies were the only class of spares available under RIW. In the model, it is assumed that any excess spare subassemblies will be disassembled and used as repairable module spares and that any remaining module spares requirements will require additional purchases.

Replenishment Spares

The replenishment spares category represents the cost to the Government of purchasing expendable or throwaway modules to replace those which are discarded after failure. It does not include parts used at organization, DS, GS, or depot repair (included in labor rates) or condemned items not normally thrown away (included in corrective maintenance repair costs).

Corrective Maintenance

The corrective maintenance of equipment can be divided into on-equipment and off-equipment maintenance. It includes the labor and material costs incurred by the Government to perform corrective maintenance at the user/DS level. Generally, such maintenance consists of a remove-and-replace action; however, certain types of equipment may require repair at the user/DS level.

Off-equipment maintenance consists of the GS and depot maintenance costs incurred by the Government. This category includes both labor and material costs.

For organic maintenance, the cost elements of corrective maintenance include the following:

- Labor and material for fault verification and module replacement
- Depot labor and material for units that are Not Repairable This Station (NRTS)
- Depot labor costs for repairable modules
- Replacement costs for condemned repairable modules

For RIW, this cost includes labor and incidental materials incurred at organization, DS, and GS to perform fault-verification activity.

Preventive Maintenance

The preventive maintenance category includes the cost incurred by the Government for preventive maintenance.

Warranty Price

The warranty price is the price paid to the contractor for supplying the warranty and associated RIW data products.

The analyst may input a warranty price if one is available. Otherwise, the model will estimate a price on the basis of the expected repair activity at his facility. The model develops the RIW price estimate to be used for early feasibility studies or independent cost assessments.

The following major cost elements are used to estimate a contractor's RIW price:

- Fixed costs for facilities and equipment
- Recurring RIW repair costs
- Warranty administration and data costs
- Risk
- Profit

Aerospace Ground Equipment (AGE)

The AGE category includes the cost of user, DS, GS, and depot test equipment that is required to support the operating equipment. Generally, more complex test equipment will be required to perform organic maintenance

than to accomplish warranty repairs. However, at transition from warranty to organic repair, additional test equipment will be required, such as that required at the depot level. Savings may be realized because the cost of additional test equipment is discounted.

Energy

Energy costs represent the direct costs of the energy or fuel used to operate the warranted equipment. These costs are entered into the LCC program as a cost per operating hour for energy for the equipment. Although this cost will often not differ between RIW and organic modes, it is included in the LCC model for two reasons:

- For some dynamic systems, energy costs are a significant proportion of LCC. Including this category can put into perspective any differences in cost between RIW and organic support alternatives.
- Small differences between the costs per hour under RIW and under organic operation can produce major LCC impacts since they are magnified by the population's operation-hour schedule. This situation can occur if, for example, a pump is manufactured and repaired under RIW with slightly greater attention to tolerances and lubrication features (to reduce the number of returns under RIW). The extra attention could affect the pump's efficiency and reduce its energy cost a few percent below the cost that would be incurred under organic support.

Overhaul

The overhaul category includes labor, material, and transportation costs to the Government of periodic overhaul or refurbishment of equipment. As with the energy category, there are two reasons for including this category in the LCC model. For some dynamic systems, this cost can be a significant contribution to LCC, and its calculation can put other cost differences into perspective. On the other hand, it may be possible to identify differences in the costs of RIW overhaul and the costs of organic-support overhaul. These differences could make sizable contributions to LCC differences.

Data

The data category includes the costs to purchase data associated with the equipment acquisition. Data for a warranty procurement are generally less expensive initially than data for organic maintenance. Therefore, at transition, the costs to purchase any additional required data are included as inputs to the model.

Inventory Management

Inventory management costs are the annual costs of managing items in the Army inventory. Only those items (parts and modules) which are unique to the equipment are included. For warranty (where maintenance is at the subsystem level), there will initially be many fewer unique items than for

organic maintenance (where depot repair will require management down to the part level). At transition, these items then become Army responsibilities.

Other

The "other" category includes any LCC factors associated with a particular procurement that are not covered by the first 11 categories in Table 10. Under organic support, this category could include the cost of reliability tests that might be run if RIW is not selected. On the other hand, this category could include any special warranty administration costs that are anticipated if RIW is selected.

8.3.3.2 Sensitivity-to-Warranty Period Analysis

Table 12 shows an RIW period analysis, which is standard output of the LCC model. For a given set of inputs, the model calculates organic-maintenance life-cycle costs ($7.3M in the table -- the same as the organic cost in Table 11 since these figures are taken from the same run). Also shown are the RIW costs for various-length RIWs. Here, the useful life of the equipment is assumed to be 10 years. Ten alternatives have been computed, with N years of RIW followed by 10-N years of organic. Each line of the table shows warranty LCC in dollars, the savings (positive number) or loss (negative number) for this alternative when compared with organic LCC, the warranty price for the alternative, and the average equipment MTBF for the alternative (which reflects any differences in warranty and organic growth rates -- none were assumed in this analysis). In Table 12, the line labeled 4.00 shows a warranty LCC and warranty price equal to those in Table 11. Thus, while Table 11 provides the details of a point-estimate comparison of RIW and organic LCC, Table 12 examines the sensitivity of LCC to the length of the RIW period. If an analyst desires to make changes to the input data, revised versions of Tables 11 and 12 can be produced to examine the impact of these changes. This is exactly the procedure that should be used in examining the economics of RIW.

TABLE 12
WARRANTY PERIOD ANALYSIS

TOTAL ORGANIC LCC = $ 7277240.

WRNTY YRS.	WRNTY LCC	SAVINGS/LOSS	WRNTY PRICE	AVG.MTBF
1.00	7306101.	-28861.	74372.	500.
2.00	7250374.	26866.	101275.	500.
3.00	7206042.	71198.	132442.	500.
4.00	7165316.	111924.	163981.	500.
5.00	7119882.	157358.	195964.	500.
6.00	7082004.	195236.	228464.	500.
7.00	7060805.	216435.	261559.	500.
8.00	7045211.	232029.	295322.	500.
9.00	7026846.	250394.	329834.	500.
10.00	7011802.	265438.	365174.	500.

SECTION NINE

SAMPLE APPLICATIONS

This section demonstrates the use of the RIW application criteria and the life-cycle-cost model through two sample applications. The intent is not to arrive at a "yes" or "no" decision on applying warranty but to indicate how these tools can be used in making such a decision. Equipment being considered for warranty would normally be subjected to analysis in relation to the warranty application criteria presented in Section Seven. If this analysis indicated no overriding factors to preclude warranty, the next step would normally be to conduct an economic analysis through use of the life-cycle-cost model, which compares major LCC elements for the warranty and organic alternatives. For ease of presentation here, we will first look at the economic analysis through use of the model and then, in Subsection 9.4, address the application criteria.

9.1 DIESEL GENERATOR

The first item considered in our sample application is a 60 kW diesel generator -- used by both the Air Force and Army in applications such as construction, standby power, computer systems, communications, and missile support. To preclude proliferation of such mobile electric-power-generating equipments, a DoD Mobile Electric Power (MEP) Project Office was initiated. The generator under analysis, the MEP-115A, is a standard unit for service use. It is procured on a periodic basis to meet combined DoD requirements. Because it is a military design, contractors must build the MEP-115A to Government specifications. Additional details on the equipment are as follows:

- Engine - 108 horsepower, 6 cylinder, 4-cycle diesel
  - Fuel consumption - 6 gallons per hour
  - Starting system includes 2 batteries and alternator
- Generator - single-bearing generator, direct-driven by engine through flexible coupling. Solid-state voltage regulator controls exciter.
- Instrumentation - Panel has voltmeter, kilowatt meter, frequency meter, temperature indicator, oil pressure gauge, battery charging ammeter, and fuel tank gauge.
- MTBF - specified at 500 hours for the system

9.1.1 Assumptions on Model Inputs

Since several data elements on the diesel generator were not available, assumptions were made in selecting figures to approximate these data. Highlights of our input data and assumptions are as follows (the input data files are provided in Appendix D):

- A total of 200 generators are being procured, with 100 delivered per year for 2 years.
- Of the 200 generators, 180 are operated an average of 60 hours per month and 20 are basically standby units that are operated an average of only 2 hours per month. To determine LCC sensitivity to higher operating time, the operating time was varied so that 180 units operated 160 hours per month and 20 units operated 80 hours per month.
- The generators are assumed to consist of an engine subassembly, with an MTBF of 2,000 hours, and a generator subassembly, with an MTBF of 666 hours. The resulting system MTBF is therefore 500 hours.
- The unit cost of a generator is $17,000 ($11,000 for the engine subsystem and $6,000 for the generator subsystem).
- No MTBF growth or decay occurs under either maintenance concept. This assumption reflects the maturity of the equipment's design.
- Time between overhauls (TBO) for the system is 3,000 hours. The overhaul cost is $1,500 under warranty and $1,700 under organic. (These values were subsequently varied to $2,000 under warranty and $3,000 under organic).
- A depot-level warranty is assumed; i.e., 90 percent of all failures are repaired at the direct or general support level, and the remaining 10 percent require depot repair (which is covered under warranty).
- The depot-repair-cycle time is 45 days under warranty and 60 days under organic.

9.1.2 Model Output

Table 13 presents a partial output of the RIW LCC model; this table shows the total ten-year discounted life-cycle costs under organic maintenance and then under warranty for each of the warranty periods. Also printed are the associated warranty savings or loss, warranty price, and average MTBF. For example, the 4.00 year line indicates a 4-year warranty followed by 6 years of organic maintenance. The LCC of this warranty/organic arrangement is $7,165,316, which is a saving of $111,924 from the 10-year organic LCC of $7,277,240. Included in the warranty LCC is the computed warranty price of $163,981. Since no MTBF growth or decay was assumed, the average MTBF during the LCC period remained at 500 hours. (The model's MTBF growth and decay features are demonstrated in Section 9.2.)

TABLE 13
ILLUSTRATIVE COMPUTER APPLICATION OF LCC MODEL
DIESEL GENERATOR (TOTAL OPERATING HOURS = 1,170,720) (SAMPLE A)

TOTAL ORGANIC LCC = $ 7277240.

WRNTY YRS.	WRNTY LCC	SAVINGS/LOSS	WRNTY PRICE	AVG.MTBF
1.00	7306101.	-28861.	74372.	500.
2.00	7250374.	26866.	101275.	500.
3.00	7206042.	71198.	132442.	500.
4.00	7165316.	111924.	163981.	500.
5.00	7119882.	157358.	195964.	500.
6.00	7082004.	195236.	228464.	500.
7.00	7060805.	216435.	261559.	500.
8.00	7045211.	232029.	295322.	500.
9.00	7026846.	250394.	329834.	500.
10.00	7011802.	265438.	365174.	500.

Table 14 presents an additional output of the model that shows the life-cycle costs for 10 years of organic and for a 4-year warranty followed by six years of organic. This output divides the total LCC into the categories discussed in Section Eight. The discounted energy (fuel) cost of over $2 million represents almost one-third of the LCC. Our input data assumed usage of 6 gallons per hour at an average cost of $.50 per gallon.

TABLE 14
ILLUSTRATIVE COMPUTER APPLICATION OF LCC MODEL
DIESEL GENERATOR (TOTAL OPERATING HOURS = 1,170,720) (SAMPLE B)

4.0 YEAR WARRANTY PRICE 163981.
PCT/YR PER INSTALLED SET 1.21

	ORGANIC	WRNTY/ORG
ACQUISITION	3400000.	3400000.
INITIAL SPARING	104000.	102098.
REPLENISHMENT SPARES	0.	0.
CORRECTIVE MAINTENANCE	264447.	214438.
PREVENTIVE MAINTENANCE	365716.	365716.
WARRANTY PRICE		163981.
AGE	235000.	185867.
ENERGY	2151270.	2151270.
OVERHAUL	320139.	320139.
DATA	50000.	37321.
INVENTORY MANAGEMENT	386669.	197167.
OTHER	0.	27321.
TOTAL	7277240.	7165316.

Although it is not shown in Tables 13 and 14, an additional output for the initial computer run was the total operating time of 1,170,720 hours for the 10-year life-cycle period. It should be noted in Table 14 that the overhaul cost ($320,139) is the same for both the organic and warranty alternatives, even though we assumed a $1,500 overhaul cost for warranty and $1,700 for organic. The reason the costs are the same in Table 14 is that for the relatively low usage or operating-hour rate, no equipments are due overhaul during the warranty period; therefore, all overhauls are performed after transition to organic maintenance.

To demonstrate the impact of an increased operating time, we revised the input so that 180 units each operate 160 hours per month and 20 units each operate 80 hours per month. The resultant total operating time was 3,283,200 hours; the revised illustrative computer runs are shown in Tables 15 and 16. While the fixed costs (such as data) remain the same, the variable costs increase the organic LCC to $13,147,208, and the warranty/organic LCC to $12,985,041 for a four-year warranty. The revised warranty price is $255,379, and the saving is $162,167. It should be noted in Table 16 that the overhaul costs are lower for warranty/organic than for organic. With this increased operating time overhauls will occur during the warranty period and will occur at a lower cost for the input assumptions we have made.

TABLE 15
ILLUSTRATIVE COMPUTER APPLICATION OF LCC MODEL
DIESEL GENERATOR (TOTAL OPERATING HOURS = 3,283,200)
(SAMPLE A)

TOTAL ORGANIC LCC = $ 13147208.

WRNTY YRS.	WRNTY LCC	SAVINGS/LOSS	WRNTY PRICE	AVG.MTBF
1.00	13167217.	-20009.	82237.	500.
2.00	13096983.	50225.	132057.	500.
3.00	13038268.	108940.	193429.	500.
4.00	12985041.	162167.	255379.	500.
5.00	12931284.	215925.	318051.	500.
6.00	12900817.	246392.	381388.	500.
7.00	12878831.	268378.	446137.	500.
8.00	12857065.	290143.	511847.	500.
9.00	12853461.	293748.	578869.	500.
10.00	12845755.	301453.	647359.	500.

To demonstrate the impact of a greater difference between the overhaul costs, we then revised the costs so that overhaul was $2,000 under warranty and $3,000 under organic. All other inputs were held constant. The results are shown in Tables 17 and 18. As a result of the increase in both costs, the organic LCC increased to $13,959,488 and the four-year warranty/six-year organic increased to $13,620,870, for a saving of $339,619. The overhaul costs under the two alternatives are shown in Table 18.

TABLE 16
ILLUSTRATIVE COMPUTER APPLICATION OF LCC MODEL
DIESEL GENERATOR (TOTAL OPERATING HOURS = 3,283,200)
(SAMPLE B)

```
 4.0 YEAR WARRANTY PRICE              255379.
PCT/YR PER INSTALLED SET     1.88
```

	ORGANIC	WRNTY/ORG
ACQUISITION	3400000.	3400000.
INITIAL SPARING	213000.	203807.
REPLENISHMENT SPARES	0.	0.
CORRECTIVE MAINTENANCE	741623.	601375.
PREVENTIVE MAINTENANCE	1025624.	1025624.
WARRANTY PRICE		255379.
AGE	235000.	185867.
ENERGY	6033081.	6033081.
OVERHAUL	1062213.	1018100.
DATA	50000.	37321.
INVENTORY MANAGEMENT	386669.	197167.
OTHER	0.	27321.
TOTAL	13147208.	12985041.

TABLE 17
ILLUSTRATIVE COMPUTER APPLICATION OF LCC MODEL DIESEL
GENERATOR (OVERHAUL COSTS: WARRANTY = $2,000, ORGANIC = $3,000)
(SAMPLE A)

TOTAL ORGANIC LCC = $ 13959488.

WRNTY YRS.	WRNTY LCC	SAVINGS/LOSS	WRNTY PRICE	AVG.MTBF
1.00	13979498.	-20009.	82237.	500.
2.00	13846855.	112634.	132057.	500.
3.00	13731405.	228084.	193429.	500.
4.00	13620870.	338619.	255379.	500.
5.00	13468126.	491363.	318051.	500.
6.00	13395033.	564455.	381588.	500.
7.00	13329991.	629498.	446137.	500.
8.00	13233855.	725633.	511847.	500.
9.00	13198225.	761264.	578869.	500.
10.00	13158170.	801318.	647359.	500.

TABLE 18

ILLUSTRATIVE COMPUTER APPLICATION OF LCC MODEL DIESEL GENERATOR (OVERHAUL COSTS: WARRANTY = $2,000, ORGANIC = $3,000) (SAMPLE B)

4.0 YEAR WARRANTY PRICE		255379.
PCT/YR PER INSTALLED SET	1.88	
	ORGANIC	WRNTY/ORG
ACQUISITION	3400000.	3400000.
INITIAL SPARING	213000.	203807.
REPLENISHMENT SPARES	0.	0.
CORRECTIVE MAINTENANCE	741623.	601375.
PREVENTIVE MAINTENANCE	1025624.	1025624.
WARRANTY PRICE		255379.
AGE	235000.	185867.
ENERGY	6033091.	6033081.
OVERHAUL	1874493.	1653928.
DATA	50000.	37321.
INVENTORY MANAGEMENT	386669.	197167.
OTHER	0.	27321.
TOTAL	13959488.	13620870.

In considering the diesel generators, we have demonstrated the impact of variations in the operating hours and overhaul costs. The capability of the model to handle further variations will be shown in the following subsection.

9.2 CONTAINER HANDLER

The second item of equipment that will be considered in our model demonstration is a 50,000 pound container handler. Four bidders competed for the Army requirement to develop a special container handler to mate with a commercial chassis of the bidders' choice. The equipment is therefore considered a military adaptation of a commercial item (MACI). The winning bid resulted in a price of approximately $175,000 per unit. Contract options provide for as many as 600 units to be delivered over a five-year period, with the first production deliveries to begin in 1980.

The solicitation for the container handlers contained a commercial vehicle warranty clause that provided for conformance with specifications for a period of six months or 600 operating hours, whichever occurred first. Anticipating that many of the vehicles would be placed in storage, the provisions also provided that in the event of storage after acceptance, the warranty period would not begin until the items were removed from storage or until six months after acceptance, whichever occurred first. An additional option provided for a 15-month or 1,500-operating-hour warranty in lieu of the six-month/600-operating hour warranty. The Army elected the 15-month/1,500-operating-hour warranty after the winning bidder offered the extended warranty period for an additional $406 per unit.

AD-A075 520 ARINC RESEARCH CORP ANNAPOLIS MD F/G 14/4
THE APPLICATION OF RELIABILITY IMPROVEMENT WARRANTY TO DYNAMIC --ETC(U)
SEP 79 A A BILODEAU , F B CRUM , W A DUNPHY DAAK70-78-C-0200
UNCLASSIFIED 1736-01-1-2025 MERADCOM-TG-1 NL

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To demonstrate application of the model, it will now be assumed that one major system of the container handler, the hydraulic actuator system, is being analyzed for application of reliability improvement warranty (RIW). The scenario is that the commercial chassis, which has been in production for several years, does not present any risk, but that the newly developed hydraulic actuator system that powers the container handler may present problems in the operational field environment. The system consists of a hydraulic reservoir, pump, pressure regulator, three identical actuators, and interconnecting lines. Any of these items can be removed and replaced at the Direct Support level, but repairs of the pump, regulator, and actuators are assumed to require depot-level maintenance because of the need for a clean-room-type maintenance environment and high-pressure test equipment.

The following data are assumed regarding the equipment:

Item	Cost	MTBF (hours)	Overhaul Cost
Pump	$700	2,000	$200
Regulator	$500	1,500	$150
Actuators	$200	1,000	$ 80

Additional assumptions used for input to the model are as follows:

- Six hundred units are delivered over a five-year period at the rate of 120 units per year. Of these yearly deliveries, one-half are put into storage and the other half are operated an average of 120 hours per month per unit.
- Average overhaul cost is $800 per system under organic and $590 under warranty.
- Average repair time is 40 days under organic maintenance and 10 days under warranty.

For the initial assumptions we have made, Table 19 shows the total 10-year discounted life-cycle costs under organic maintenance and then under warranty for each of the measurement periods. Based on constant MTBF of 240 hours, the four-year warranty price is $297,915, which results in a saving of $119,720 over full organic maintenance for the 10-year life cycle. It should also be noted in the table that for the input assumptions we have made, the greatest savings ($258,067) occur with an eight-year warranty before transition to organic maintenance.

Two runs were made to show the impact of MTBF variations. First, we assumed no MTBF growth under organic and a 5 percent growth for warranty. See Appendix D, Subsection 3.2.1 for a discussion of the growth model used in this program.

In Table 20, the MTBF grows, under RIW, to 260 hours at the four-year transition point and then remains constant during the remaining six years of organic maintenanc. In Table 21, this growth results in a warranty saving of $228,374, almost double the saving of the previous "no growth" example.

TABLE 19
ILLUSTRATIVE COMPUTER APPLICATION OF LCC MODEL
HYDRAULIC ACTUATOR SYSTEM (MTBF = 240 HOURS)

TOTAL ORGANIC LCC = $ 5412514.

WRNTY YRS.	WRNTY LCC	SAVINGS/LOSS	WRNTY PRICE	AVG.MTBF
1.00	5462866.	-50352.	82167.	240.
2.00	5411643.	872.	131785.	240.
3.00	5350350.	62165.	203965.	240.
4.00	5292795.	119720.	297915.	240.
5.00	5234518.	177996.	412938.	240.
6.00	5193507.	219007.	533792.	240.
7.00	5162808.	249706.	666157.	240.
8.00	5154447.	258067.	795326.	240.
9.00	5160690.	251824.	926595.	240.
10.00	5178390.	234125.	1060269.	240.

TABLE 20
ILLUSTRATIVE COMPUTER APPLICATION OF LCC MODEL HYDRAULIC ACTUATOR
ASSEMBLY (MTBF GROWTH: WARRANTY = 5 PERCENT, ORGANIC = 0 PERCENT) (SAMPLE A)

```
WARRANTY/ORGANIC MTBF GROWTH

1 248.4295107383
2 254.2400993782
3 257.4248779427
4 259.5737524867
--TRANSITION--
5 260.4181825309
6 260.4181825309
7 260.4181825309
8 260.418182531
9 260.4181825309
10 260.4181825309
```

An additional variation was made to indicate the impact of a decay in MTBF. Here it was assumed that under warranty the MTBF was constant, but under organic maintenance the MTBF decayed 5 percent. The results are shown in Tables 22 and 23. Table 22 shows the MTBF decay under the full organic alternative; Table 23 shows the resultant MTBF and LCC data for various warranty periods. For example, a constant MTBF for a four-year warranty followed by decay under organic maintenance results in an average MTBF of 238 hours over the 10-year life cycle. The warranty savings under these circumstances are $244,230. A shorter warranty period and therefore longer repair period with more decay results in a lower average MTBF and less savings. For example, a one year warranty and nine years' decay under organic results in an average MTBF of 230 hours and a reduced savings of $82,167.

TABLE 21
ILLUSTRATIVE COMPUTER APPLICATION OF LCC MODEL HYDRAULIC ACTUATOR ASSEMBLY (MTBF GROWTH: WARRANTY = 5 PERCENT, ORGANIC = 0 PERCENT) (SAMPLE B)

TOTAL ORGANIC LCC = $ 5412514.

WRNTY YRS.	WRNTY LCC	SAVINGS/LOSS	WRNTY PRICE	AVG.MTBF
1.00	5395923.	16591.	81755.	252.
2.00	5322484.	90030.	129403.	256.
3.00	5249256.	163259.	197715.	258.
4.00	5184141.	228374.	285773.	260.
5.00	5120136.	292379.	392818.	261.
6.00	5074782.	337732.	509426.	261.
7.00	5040257.	372258.	627154.	262.
8.00	5027718.	384796.	746351.	262.
9.00	5029445.	383069.	867343.	262.
10.00	5043127.	369388.	990441.	262.

TABLE 22
ILLUSTRATIVE COMPUTER APPLICATION OF LCC MODEL HYDRAULIC ACTUATOR ASSEMBLY (MTBF GROWTH: WARRANTY = 5 PERCENT, ORGANIC = -5 PERCENT) (SAMPLE A)

ORGANIC MTBF GROWTH

1	231.4074503089
2	225.8829893557
3	222.9494718573
4	221.0104731405
5	219.5666963522
6	218.4633856381
7	217.6351143547
8	216.9966370615
9	216.477082264
10	216.039123845

9.3 MODEL APPLICATION SUMMARY

In order to demonstrate the model application, several variations were made in input assumptions for two items of equipment. As indicated at the beginning of this section, the intent was not to arrive at a "yes" or "no" decision on applying warranty, but to indicate how the model can be used to aid in such a decision. For the equipment and assumed data in our examples, the resultant warranty savings are relatively small in relation to the overall life-cycle costs. For example, in the case of the diesel generator

TABLE 23

ILLUSTRATIVE COMPUTER APPLICATION OF LCC MODEL HYDRAULIC ACTUATOR ASSEMBLY (MTBF GROWTH: WARRANTY = 5 PERCENT, ORGANIC = -5 PERCENT) (SAMPLE B)

TOTAL ORGANIC LCC = $ 5549478.

WRNTY YRS.	WRNTY LCC	SAVINGS/LOSS	WRNTY PRICE	AVG.MTBF
1.00	5523519.	25958.	82167.	230.
2.00	5446419.	103058.	131785.	234.
3.00	5371358.	178119.	203965.	236.
4.00	5305247.	244230.	297915.	238.
5.00	5241439.	308039.	412938.	239.
6.00	5196866.	352612.	538792.	239.
7.00	5164375.	385103.	666157.	240.
8.00	5155042.	394436.	795326.	240.
9.00	5160820.	388658.	926595.	240.
10.00	5178390.	371088.	1060269.	240.

a saving of $200,000 represents less than 2 percent of the approximate $13 million LCC; in the case of the hydraulic system the same saving represents slightly less than 4 percent of the $5.5 million LCC. In some situations the economic analysis will clearly favor or disfavor warranty; in other cases the economic advantage may be so small that other considerations may prevail. Warranty application criteria discussed in the following section will be especially important in these middle-of-the road situations.

9.4 WARRANTY APPLICATION CRITERIA

As indicated at the beginning of this section an equipment under consideration for warranty is usually evaluated in relation to warranty application criteria before the economic analysis is performed. Because we were considering two equipments, it was easier for presentation purposes to reverse the normal order.

Table 24 lists the application criteria that were discussed in Section Seven. Opposite these criteria in the table are comments for each of the two items of equipments being considered. As noted, the equipments meet many of the criteria. However, in the case of the diesel generator, one important criterion is not met ("The RIW equipment design has been developed or controlled by the offeror,"). With the equipment design controlled by the Government, the contractor's liability could be limited to correcting defects in material and workmanship or being responsible for failure to conform to specifications. Additionally, as indicated under item 2a in the Table, it appears that the equipment design is very mature and that there may be little opportunity for reliability growth. A final criteria worthy of note is item 4a. Either not performing required preventive maintenance,

or inducing failures while performing it, could result in many items being excluded from warranty coverage. The impact of this factor could be minimized through stringent maintenance control; however, for the two items previously mentioned there is little that can be done to lessen their impact. As a result, the application criteria coupled with the relatively small warranty savings for our data assumptions, suggests that the diesel generator is not a good candidate for warranty.

Although additional analyses is required for some of the criteria pertaining to the hydraulic actuator system, none of the factors examined preclude warranty application. Depending on the MTBF growth/decay assumptions, Section 9.3 indicated a range of potential savings for warranty application. For example, Table 24 indicates an 8 year warranty savings of $394,436; this would represent approximately a 7 percent reduction from the $5,549,478 organic LCC. Therefore, this initial analysis indicates that the actuator system appears to be a viable candidate for warranty application and that a more in-depth analysis would be justified.

TABLE 24
EVALUATION OF APPLICATION CRITERIA*

Criterion	Diesel Generator	Hydraulic Actuator System
Procurement		
The procurement will be on a fixed-price basis.	Yes	Yes
Multiyear funding is available for RIW.	Unknown-would require determination.	Unknown-would require determination.
The procurement is competitive	Yes	Yes
The RIW equipment design has been developed or controlled by the offeror.	No	Additional analysis required-some elements of design may have been outside contractors control.
Potential offerors have proven capability and experience in supporting equipment.	Yes	Yes
Production/deployment/usage schedules support the RIW goals and requirements.	Additional analysis required due to variable deployment/usage schedules.	Additional analysis required - planned storage of significant quantities may preclude desired usage and feedback.
Administration of RIW can be efficiently planned and administered.	Additional analysis required. An inventory mix of new warranted items with existing unwarranted items would be difficult to administer.	Additional analysis required-administration system may be established-no inventory mix problems since new items.
Equipment		
The maturity of equipment reliability is at an appropriate level.	Additional analysis required - appears that design is very mature - may be little opportunity for growth.	Additional analysis required - opportunity for growth may be present.
Item can be marked or labeled to show existence of RIW coverage.	Yes	Yes
The item operates independent of other systems not covered by the RIW.	Yes	Yes
The item has a modular design to simplify fault isolation.	Yes	Yes
An elapsed-time indicator (ETI can be installed on the item).	Yes	Additional analysis required - ETI would provide chassis operating time, the operating time of container handler actuator assembly may have to be prorated.
Operations		
Use environment is known or predicatable.	Except for operating rates use environment is generally known.	Uncertainty on storage and possible preservation requirements indicates need for further analysis.
Item operational reliability and maintainability are predictable.	Yes	Yes
Item wartime or peacetime mission criticality not impacted.	Additional analysis required - some percent of total quantity may be very critical in wartime.	Additional analysis required - some percent of total quantity may be very critical in wartime.
Operational failure and usage data can be supplied to the contractor.	Additional analysis required on capability of data systems.	Additional analysis required on capability of data systems.
Sufficient data will be available to compute or estimate MTBF or other reliability parameters.	Additional analysis required on capability of data systems.	Additional analysis required on capability of data systems.
Support		
There is little opportunity to induce failures during Preventive Maintenance and Inspection (PM&I) Activity. Failures are not likely to be induced if PM&I is not performed as required.	Opportunity to induce failures is relatively high.	Opportunity to induce failures is relatively low.
Contractor can verify performance of PM&I	Yes	Little to no PMI applicable.
Unauthorized maintenance can be controlled.	Additional analysis required - unauthorized maintenance may be likely.	Equipment design should minimize unauthorized maintenance, but additional analysis required.
Item is field testable without extensive disassmebly.	Yes	Yes
User and maintenance organizations have appropriate transportation/packaging capabilities to support RIW.	Yes	Yes

*Yes or No indicates that criteria is or is not met.

SECTION TEN

CONCLUSIONS

On the basis of investigations conducted for this study, the following conclusions are made:

- Commercial Warranties for Dynamic Systems - In the commercial marketplace, the manufacturer uses warranty as a marketing and sales tool in a competitive environment. Buyers will use it, if convenient, as a cost-avoidance tool. Not all buyers are interested in this aspect of their equipment purchase.
- Military Adaptations of Commercial Warranties - The Army has adapted commercial warranties for vehicles for several years. Improvements in administration would further increase benefits to the Government. When adapted for service purchases, commercial warranty practices present an opportunity for reduced material costs, and perhaps labor costs, when properly applied. However, there appears to be little direct opportunity to influence equipment design or improve equipment reliability and maintainability characteristics for a specific procurement.
- Current RIW Guidance - Current RIW guidelines primarily address the characterisitcs of avionics equipment and the environment in which this equipment is operated and maintained.
- Avionics versus Dymanic Systems Environments
  - There are differences between the avionics system and dynamic system environments that can prevent, limit, or otherwise restrict the direct application of existing RIW practices. While some of these differences are related to design aspects of dynamic systems, others -- equally important -- are due to procurement, operational, and support factors. These factors can reduce a contractor's opportunity and incentive to meet the goals of RIW.
  - Selection of appropriate candidates for RIW among dynamic systems is more difficult than among avionics equipments because dynamic systems have greater dependence on commercially available items and are subject to greater variability in operating and support conditions.

* RIW for Dynamic Systems
  * The RIW application criteria developed in Section Seven are adapted from existing avionics criteria and address the differences that have been observed between RIW avionics and dynamic system procurements.
  * Two types of dynamic system RIW plans have been identified; when properly applied, they offer the potential of meeting the goals that RIW is achieving in avionics procurements.
  * A limited number of RIW-type contracts now exist for dynamic systems. They have been applied to aircraft-related systems, in contrast with the fixed or mobile ground-based systems procured at MERADCOM.

SECTION ELEVEN

RECOMMENDATIONS

On the basis of our investigations and the conclusions stated in Section Ten, the following recommendations are made:

- Identification of RIW Candidates
  - The project managers and laboratories at MERADCOM should review current and projected programs to identify programs that have potential for the application of RIW. The application criteria in this report, together with any appropriate LCC model, can be used to accomplish this review. Of particular interest should be programs approaching or entering full-scale engineering development, expecting competitive bids for production, and containing newly developed dynamic systems rather than systems adapted from commercial designs. These programs should offer the greatest potential benefits from use of RIW.
  - A small number of items from the identified candidates should be selected as test cases for the application of RIW to dynamic systems. Decisions to pursue RIW can be made after detailed administrative and economic analyses are completed (preferably during FSED). A final decision to apply RIW can be made during source selection for a production contract.
- RIW Administration
  - For the initial equipments that are procured by MERADCOM under RIW, it is recommended that management responsibility for that equipment remain with the cognizant MERADCOM office throughout the RIW period. During these test applications, it is important to retain continuity of contract administration and RIW implementation.
  - A field data collection and analysis program should be established for these test applications of RIW. The data should be used to evaluate the quality of implementation and evaluate administrative problems that arise during implementation and to assess the value of the RIW programs in these applications.

As these recommendations are being implemented, we also recommend that a single point of contact be established at MERADCOM to coordinate RIW activity within the command and to update periodically the dynamic system warranty experience identified in this report. This point of contact should be identified to the DARCOM Directorate for Quality Assurance, which is responsible for Army warranty review.

APPENDIX A

LDNS RIW TERMS AND CONDITIONS

This appendix contains Warranty Terms and Conditions for the Singer-Kearfott Initial Production Contract DAAB07-77-C-2126 for LDNS.

WARRANTY TERMS AND CONDITIONS

Part I - Statement of Warranty

1. Notwithstanding Government inspection and acceptance of supplies and services furnished under this contract or any provisions of this contract concerning the conclusiveness thereof, the Contractor warrants that each Lightweight Doppler Navigation System AN/ASN-128(XE-2) consisting of:

Receiver-Transmitter-Antenna, Radar RT-1193(XE-2)/ASN-128,
Computer Display Unit CP-1252(XE-2)/ASN-128, and
Converter, Signal Data, Radar CV-3338(XE-2)/ASN-128

(hereinafter referred to as Units) furnished under this contract will be free from defects in material, workmanship, and design and will operate in its intended environment in accordance with contractual specifications of this contract for the warranty period set forth herein and as it may be renewed under the provisions hereof. This warranty is in addition to and does not affect or limit the Government's rights under any other provision of this contract.

2. Any Unit furnished under this contract that fails to meet the aforesaid warranty and is returned to the Contractor by the Government shall be either repaired or replaced at the Contractor's sole option and expense, so as to operate in accordance with said contractual specifications. Satisfactory operation of a Unit shall be demonstrated by successful completion of the Acceptance Test Procedure (ATP) contained in CDRL Item No. 0013AF. The Contractor is not required to perform cosmetic repairs on Units returned under this warranty. Unless agreed to otherwise by the Government, all warranty repair and test activity shall be performed by the Contractor. The Government shall have the right to witness test activity and review the documented results.

3. For the purposes of this warranty, the Initial Anniversary Date (IAD) shall be defined to be the date of successful completion of DT III PVT-G (Production Validation Testing - Government) testing. The Contractor will be notified of the IAD date by the ACO prior to release of the PVT-G Test Report. In any event, such notification will occur no later than 90 days after the successful conclusion of PVT-G testing. This IAD will be used to establish reporting and adjustment periods for this warranty.

4. For all Low Rate Initial Production (LRIP) Units purchased under this contract, the initial warranty period shall start upon government acceptance of the Unit (signing of the DD250) and shall extend until 48 months after the IAD defined in Part I, paragraph 3. The warranty period specified herein may be renewed for additional periods at the option of the Government. The Contracting Officer and the Contractor agree to negotiate in good faith the price for any renewal of the warranty period.

5. The Contractor shall not be obligated to pay for the repair or replacement of any Units under this warranty for nonconformance, loss, or damage by reason of (1) Non-LDNS induced fire, (2) non-LDNS induced explosion, (3) submersion, (4) aircraft crash, (5) enemy action, (6) natural disaster, such as flood, hurricane, tornado, earthquake, or lightning, or (7) accidental or willful mistreatment. These exclusions apply only to loss or damage occurring at locations other than those owned or controlled by the Contractor or where a defect in the Unit is not a cause of one or more of the above listed events. Clear and convincing evidence must accompany the Contractor's claim for relief from warranty obligation for any of the above listed exclusions.

While broken seals per se are not cause for exclusion from the warranty provision, the Contracting Officer will consider this together with all other evidence which may be submitted by the Contractor in support of a claimed exclusion from the warranty provisions.

6. Notwithstanding the provisons of the "Inspection" (1958 May) Clause (ASPR 7-103.5(a)) regarding the conclusiveness of acceptance and the waiver of defects which are susceptible to discovery prior to acceptance, the Contractor shall be obligated to repair or replace any defective Unit in accordance with the terms and conditions of this warranty. The rights and obligations of the parties under this warranty are in addition to and independent of the rights and obligations of the parties under the other provisions of this contract. Except as provided by the general provision of this contract entitled "Inspection", the Contractor's obligations and the Government's remedies for repair and replacement are solely and exclusively as stated herein. In no event shall the Contractor be liable for special or consequential damages.

Part II - Contractor Obligations

1. Contractor-initiated ECPs to improve Unit reliability or maintainability at no change in contract price are encouraged under this warranty. All Government approved no change in price ECPs shall be incorporated into all new production units and into applicable prior production Units returned by the Government to the Contractor for repair. As a part of each no change in price ECP, the Contractor agrees to submit a schedule of prices to the Government for supplying the necessary parts (modification kits, instructions or other necessary material and supplies) for Units in the Government inventory for which the warranty has expired or will expire and which are known not to be of the latest configuration. The Government option to buy these necessary parts (modification kits, etc.) at the ECP price schedule shall extend until the earliest warranty expiration date for the LDNS, as a minimum.

This provision does not limit the Contractor's rights or privileges to develop and submit cost ECPs for other purposes.

2. The Contractor shall cause a suitable and prominent display of warranty information in form and content suitable to the Contracting Officer to be placed conspicuously on the surfaces of each Unit under warranty. A typical example is shown in Figure 1.

3. The Contractor shall cause a suitable label for permanently recording Unit installation and removal data in form and content suitable to the Contracting Officer to be placed conspicuously on the surface(s) of each Unit under warranty. A typical example is shown in Figure 2.

WARRANTY NOTICE

1. This unit is under warranty until (Date to be inserted).
2. Do not break or tamper with warranty seals.
3. Verify failures using approved procedures and test equipment of TM (To be inserted).
4. Record failure circumstance data and line tester findings on (Appropriate form reference to be inserted).
5. Package in accordance with Section II of TM (To be inserted) and promptly return with failure circumstance data and line tester data to (Insert contractor's address).

FIGURE 1 (Typical)

	Installation Data				FOR CONTRACTOR
	Date and Time Totalizing Meter				USE ONLY
	Installed	Time	Removed	Time	Code
1					
2					
3					
4					
5					
6					

FIGURE 2 (Typical)

Note that there is a "Code" column next to the removal data in which the Contractor will record, on returned Units only, a code representing the result of Contractor/ACO action. The coding scheme is as follows:

0 - Unit removed for other than warranty repair

1 - Failure not covered under warranty (ACO concurrence)

2 - Failure verified, corrective action taken under warranty

3 - Failure not verified (ACO concurrence)

4. The Contractor shall provide and install appropriate seals for all Units which shall minimize inadvertent seal breaking. Furthermore, the design of the seals should be such that a breaking of a seal through tampering is detectable.

5. The Contractor shall submit for Government approval the proposed content, wording, placement, material, and method of application of the items required in Part II, paragraphs 2, 3, and 4.

6. The Contractor shall insert a notice in all technical manuals that cover the Units, to the effect that they are under warranty. The Contractor shall place those warranty provisions applicable to using activities in all pertinent Technical Manuals developed under this contract.

7. The Contractor shall maintain throughout the warranty period a fully operational warranty-repair facility located in the Continental United States. The Contractor shall maintain at this repair facility a secure area for storage of Government-owned spare units and repaired units.

8. In the event of a failure of a Unit, the Government shall promptly notify the Contractor in writing or by electronic message (e.g., TWX) of said failure.

Upon receipt of such notification, the Contractor shall package and pack in accordance with best commercial packaging practices and ship a replacement Government-owned Unit from the secure storage area to a location designated by the Government. To the extent possible, Units will be selected for shipping from the secure storage area on a first-in/first-out (FIFO) basis. Such shipment shall be made within one working day from the time of receipt of notification, but in no event shall such shipment be made later than 96 hours after receipt of notification. For shipment, the Contractor shall use a Government Bill of Lading (GBL) accompanied by a DD Form 1149 for transfer of Government property accountability. In the event there are insufficient Units in the secure storage area to meet demands, the Contractor shall follow a shipping-priority system as directed by the ACO.

9. Units returned to the Contractor for repair or replacement under this warranty for which the Contractor cannot verify any nonconformance shall be subjected to and pass this contract's approved test procedure, packaged, and

delivered to the secure storage area by the Contractor. This shall be done at no change in contract price unless the number of such returns exceeds (a) an average of two such returns per month or (b) 25% of the total number of all returned Units in the reporting period, whichever figure is greater. For purposes of this adjustment, the reporting periods are defined to be twelve month periods beginning with the IAD. The Contracting Officer will annually adjust the contract price and make payment to the Contractor at the rate of $200 per Unit for the number of such returns that exceed the foregoing amount in each reporting period. For the purposes of computation, the returns of all Units will be combined. The Contractor shall promptly present evidence to the ACO or his designated representative that nonconformance of a returned Unit cannot be verified. The ACO shall review and corroborate this determination.

10. The Contractor shall repair, replace and/or install approved ECP modifications, perform and pass the Contract's approved test procedure, package, and store a returned Unit for which this warranty is in force in the secure storage area in an average time less than or equal to "Tspec" calendar days as defined herein. Each Unit's turnaround time starts on the day it is received at the Contractor's repair facility and joint inspection is made by the Contractor and Government representative and ends on the day it is placed in the secure storage area or shipped to a Government location.

Calculation of the Contractor's average turnaround time shall be made over six-month periods. The first such period shall start with the initial anniversary date, and subsequent six-month periods shall follow consecutively until warranty termination. If the average turnaround time in a six-month period exceeds the specified value, as computed from warranty data records, the Contractor will be assessed a liquidated damage in accordance with the following formula:

$$\text{Liquidated Damage} = \$25 \times (\overline{T} - T_{spec}) \times R$$

This formula is based on a liquidated damage of $25 per day for each Unit which, on the average, exceeds the specified turnaround time. Such a fixed amount is established and agreed to by the Contractor in recognition of the fact that actual liquidated damages are difficult, if not impossible, to determine.

In this formula:

R = number of returned Units that have been received by the Contractor during the six-month period and which are not subject to the exclusions of Part I, paragraph 5.

$\overline{T}$ = average turnaround time of the R returned Units during the six-month period calculated to three decimal places from the equation $\overline{T} = D/R$. D is defined as the total number of calendar days for Contractor processing of the R items returned for warranty service.

T_{spec} = Specified turnaround time = $T_c + T_m$

The following table defines Tc for each measurement interval:

Interval	Tc(calendar days)
IAD to IAD + 6 mos	30
IAD + 6 mos to IAD + 12 mos	25
IAD + 12 mos to IAD + 18 mos	20
Intervals after IAD + 18 mos	15

Tm is a turnaround time adjustment which depends on achieved MTBF and is defined in Part V, paragraph 5.

Liquidated damages will not be due for a measurement period if, during the period (see Part II, paragraph 8)

(a) The Government contractor had sufficient assets in the bonded storeroom to meet each asset demand during the period, and

(b) each such demand was met within the 96 hour time limit.

The Contractor shall not be charged with liquidated damages when the delay arises out of causes beyond the control and without the fault or negligence of the Contractor and its Sub-contractors, as defined in paragraph (c) of the Default clause of the contract.

11. The Contractor shall have a continuing responsibility to accept for correction and ECP installation and to complete the correction or ECP installation of, or furnish a replacement for, any Unit shipped to the Contractor's repair facility with a shipping date on or before the last day of the warranty period as extended *notwithstanding any other provisions* of this warranty. Any replacement units furnished under this warranty must be of the latest configuration and must pass the applicable ATP.

12. The Contractor shall maintain records by serial number for each Unit under warranty as required in Part VI hereunder. These records shall be made available to the Government at the Contractor's plant upon request during the warranty period and for two years following the expiration of warranty on any LRIP Unit.

Part III - Government Obligations

1. The Government shall, to the extent possible, verify failures utilizing Government/Contractor approved technical orders prior to the return of Units to the Contractor, provide failure date and failure circumstance data to the Contractor, and use appropriate packing and packaging when returning Units under warranty. However, in the event that any or all of these conditions are not met, the warranty shall remain in effect for such Units.

2. In recognition of the high contractor motivation for total cost control effectiveness through the incentive feature of this warranty, the Government agrees that all no change in contract price ECPs which are complete and submitted in accordance with MIL-STD-480 to improve reliability

or maintainability of the Units will receive expeditious processing through the approval cycle. Notwithstanding this special processing, any such ECP shall be automatically incorporated in the contract by the Government thirty-five (35) calendar days after receipt of such ECP by the PCO unless the PCO has issued a written notification of its non-approval prior to that date. ECPs developed and submitted for other purposes will be subject to the normal ECP review cycle.

3. The Government shall establish within its organization a single point of contact to communicate with the contractor its requirements under RIW including, but not limited to, shipping instructions and establishment of priorities on shipments.

4. Analyses which identify contract price adjustments or needs for engineering analysis or corrective engineering actions in Parts IV and V shall be reviewed by the Contracting Officer and approved by him prior to implementation of these actions. The Contracting Officer's decision shall be final.

Part IV - Miscellaneous

1. Upon receipt of a returned Unit at the Contractor's plant or repair facility, a joint inspection shall be made by the Contractor and the resident Government quality assurance representative for the purpose of categorizing the warranty status of each Unit. The representative shall report his findings to the contracting officer. There is a presumption that a returned Unit is covered under this warranty and only the provisions of Part I, paragraph 5 thereof shall void the Contractor's responsibility to repair or replace at no cost to the Government under this warranty. In the event of a controversy, the Government reserves the right to make a final determination as to whether any Unit is covered by this warranty. The Contractor may exercise his prerogative under the Disputes Article of the contract.

2. The Contractor agrees to enter into a separate contract with the Government to cover the correction, repair, replacement, or disposition of Units that have sustained damage attributable by the Government to the causes/events set forth in Part I, paragraph 5.

Each such Unit returned for repair which upon examination at the Contractor's facility is not considered by the Government to be economically repairable shall be disposed of by the Contractor as directed by the contracting officer. The Contractor shall have the right to assess charges for any reasonable services performed as directed by the contracting officer in connection with the disposition of any such nonrepairable Unit. Any material required to be furnished by the Contractor in connection with shipment of such Units shall be subject to equitable adjustment. The Contractor may retain any such Units with the approval of the Contracting Officer if reimbursement is made to the Government for its reasonable value.

3. Any Unit returned to the Government after replacement hereunder shall have applied hereto the balance of the warranty period of the Unit it replaces.

When more than 10 percent of the Units provided under this contract have sustained damage attributable by the ACO to the causes/events set forth

in Part I, paragraph 5, and are not corrected or replaced under the provisions of Part IV, paragraph 2, or have otherwise been certified by the Contracting Officer as lost or damaged beyond repair, an adjustment in contract price shall be made for the unused portion of the warranty for the Units exceeding the 10 percent threshold.

For each Unit for which such adjustment is applicable, the Contractor shall rebate the Government at the rate of 0.0160 percent per day per Unit of the system RIW price in CLIN 0016AA. The rebate will apply to the unused portion of warranty time starting with the day the Unit was declared lost or damaged beyond repair.

5. The Government shall not be obligated to provide facilities, tooling, or equipment of any type for Contractor performance under this warranty except where Government Furnished Property is identified in the contract.

6. An average operate time of twenty (20) hours per month for each Unit delivered to the Government is expected for the LDNS equipment. Starting twenty-four (24) months after the Initial Anniversary Date (as defined in Part 1, paragraph 3) and annually thereafter, the contract price shall be adjusted upward or downward to account for significant deviations (greater than plus or minus 10%) from this 20-hour standard during the previous twelve (12) month period. No adjustment shall be made for an operating differential in the period between contract award and twelve (12) months after the initial anniversary date.

Such adjustments shall be made by analyzing the elapsed-time-indicator (ETI) readings of all returned Units during the preceding twelve (12) months to estimate total operating time and comparing this estimate with the expected total operating time based on a 20 hour per month average.

Expected total operate hours (EXTOH) over an M month period is calculated as follows:

$$EXTOH = \bar{N} \times \overline{OT} \times M$$

where

$$\bar{N} = \frac{1}{3.M} \sum_{j=1}^{M} Nj$$

and

Nj is the total number of LDNS Units accepted by the Government through the end of month j of the M month interval

$\overline{OT}$ = 20 hours per month, the expected average operate time per month per Unit

M = number of months in the period

Estimated Total Operate Hours (ESTOH) over an M month period is calculated as follows:

$$ESTOH = D \times \overline{AOT} \times \bar{n}$$

where

D = number of calendar days in the M month period

$\overline{AOT}$ = estimated average operate time per day

$$= \frac{\sum_j \Delta Time_j}{\sum_j \Delta Days_j}$$

$$\bar{n} = \frac{1}{3.M} \sum_{j=1}^{M} \bar{n}_j$$

and n_j is the total number of LDNS Units accepted by the Government which are under warranty, and not at the Contractor's repair facility or in his secure storage area at the end of month j of the M month interval.

All Units received at the Contractor's repair facility during the measurement period will be used to compute $\overline{AOT}$.

Δ $Time_j$ for a Unit returned during the measurement period is defined to be the ETI reading of the Unit when received by the Contractor minus the ETI reading of the Unit when last shipped by the Contractor. Δ $Days_j$ for a Unit returned during the measurement period is defined to be the total number of calendar days the Unit was out of the Contractor's repair facility or secure storage area starting with the date the Unit was last shipped to a Government installation up to the date the Unit was again received by the Contractor. It is noted that the values in the numerator and denominator of the above equation must be based on the same Units. If the Unit's ETI is inoperative or its data not available, then that Unit's data shall be excluded from the calculation of $\overline{AOT}$.

The usage ratio (UR) for the measurement period is given by:

$$UR = \frac{ESTOH}{EXTOH}$$

The correction factor (CF) for warranty payment for the period is given by

$$CF = \begin{cases} \frac{5(UR) + 4.5}{9} & 0 \leq UR < .9 \\ 1.0 & .9 \leq UR \leq 1.1 \\ \frac{5(UR) + 3.5}{9} & 1.1 < UR \end{cases}$$

The warranty price adjustment (AWP) due to equipment usage over the interval is calculated in two parts. For systems supplied under CLIN 0001AA:

$$AWP1 = \frac{CF - 1.0}{4} \, CLINP$$

where CLINP is the price of CLIN 0016AA

For systems supplied under the option quantity provisions of this contract:

$$AWPO = (CF - 1.0)\frac{QS}{QO}\left[\frac{PRICE}{3}\right]$$

where QO is the total option quantity exercised,

QS is the number of option quantity systems accepted by the Government by the last day of the usage measurement period, and

PRICE is the option quantity RIW price for QO systems.

Then

$$AWP = AWP1 + AWPO$$

A positive AWP indicates that the price is adjusted upward. A negative AWP indicates that the price is adjusted downward.

Part V - MTBF Guarantee

1. The Contractor shall guarantee that the achieved MTBF of the LDNS will be equal to or greater than that shown below:

Period	LDNS Achieved MTBF
1 through 48 months after IAD	500 hours

2. For this guarantee, the method for measuring achieved MTBF of the LDNS is given in Part V, paragraph 6.

3. The Contractor shall make semi-annual measurements of achieved MTBF of the LDNS over the previous six (6) month period. The first such measurement shall be made eighteen (18) months after the IAD. Paragraph 6 of this section provides the method for measuring achieved MTBF. The Contractor's obligation with respect to this MTBF guarantee shall terminate when three (3) consecutive measurements yield MTBF values that equal or exceed the guaranteed MTBF value shown in Part V, paragraph 1. In no event shall the Contractor's obligation be continued beyond forty-eight (48) months after the IAD unless mutually agreed to otherwise. Notwithstanding the termination of this MTBF Guarantee, the RIW shall continue in accordance with the applicable provisions of that clause.

4. In the event that the achieved MTBF for any measurement period is less than 500 hours, the Contractor shall furnish to the Government, at no additional cost to the Government, the following:

(a) Engineering analysis to determine the reasons for the failure to achieve the guaranteed figure

(b) Corrective engineering design changes

(c) Modification of the Units, as required.

5. *In Part II, paragraph 10, the turnaround time adjustment factor* (Tm) for a given period will depend on the achieved MTBF of the previous measurement period as follows:

Achieved MTBF (hours)	Tm (calendar days)
Less than 400 hours	-4
400 hours to 600 hours	0
more than 600 hours	4

6. This paragraph provides the method for measuring achieved MTBF over a six-month measurement period.

Achieved MTBF is defined as follows:

$$MTBFA = \frac{ESTOH}{F}$$

where

MTBFA = achieved MTBF

ESTOH = the estimated total operate hours of the LDNS over the six month period (See Part IV, paragraph 6, with M = 6)

F = number of Units received at the Contractor's repair facility during the measurement period which are coded '2' in accordance with Part II, paragraph 3.

Part VI - Data Requirements

The contractor shall establish and maintain a data accumulation, processing, analysis and reporting system capable of providing the information required by the following data items:

CDRL	Data collection and Analysis Plan
CDRL	Warranty Data Report
CDRL	Warranty Effectiveness Study

APPENDIX B

RIW DATA ITEMS FOR THE LDNS

The Contract Data Requirement List (CDRL), for the LDNS DD Form 1423, and supplemental instructions for items required to support RIW are included in this appendix.

ATCH NR 11 TO EXHIBIT (CLIN 0016)

CONTRACT DATA REQUIREMENTS LIST

SYSTEM/ITEM Lightweight Dop. NAV Sys AN/ASN-128

TO CONTRACT/PR ______ CATEGORY R CONTRACTOR ______

1. Sequence Number	2. Title or Description of Data / 3. Subtitle	4. Authority (Data Item Number)	5. Contract Reference	6. Technical Office	7. DD 250 Req	8. Appr Code	9. Input to IAC	10. Frequency	11. As of Date	12. Date of 1st Submission	13. Date of Subsequent Subm/Event ID	14. Distribution and Addressees (Addressee – Regular Copies/Repro Copies)	15. Total
11-36	Assessment Program Plan / Data Collection and Analysis Plan	DI-R-1750	0016BM See Sub-section F.53	W15P85	DD	A		O/Time		90 Days	After Submis of draft	W15P85 1/0; PM-NAVCON 2/0	3/0
16. Remarks	Delete Block 10 Preparation Instruction on DD Form 1664. Prepare in accordance with supplemental instructions to DI-R-1750 Two (2) draft copy req'd 190 days ADAD, ATTN:W15P86. Sixty (60) days req'd for Gov't review of draft.												
11-37	Assessment System Perf. Status Rpt. / Warranty Data Report	DI-R-1753	0016BN See Sub-section F.53	W15P85	DD			Semi Annual		See Block 16		W15P85 1/0; PM-NAVCON 2/0	3/0
16. Remarks	Delete Block 10 Preparation Instruction on DD Form 1664. Prepare in accordance with supplemental instructions to DI-R-1753. DD Form 250 req'd with final submission only. Submission IAW supplemental instructions.												
11-38	Assessment System Perf. Status Report / Warranty Effectiveness Study	DI-R-1753	0016BP See Sub-section F.53	W15P85	DD			Annual		See Block 16		W15P85 1/0; PM-NAVCON 2/0	3/0
16. Remarks	Delete Block 10 Preparation Instruction on DD Form 1664. Prepare in accordance with supplemental instructions to DI-R-1753. DD From 250 req'd with final submission only. Submission IAW supplemental instructions.												

17. Exhibit/Attachment Number	18. DD Approval/Form Number	19.–21. Reserved for ADP	22.	23. Contractor File/Document Number	24. Estimated Number of Pages	25. Price Group	26. Estimated Total Price

CONTRACT VALUE

PREPARED BY ______ DATE ______ APPROVED BY ______ DATE ______

DD FORM 1 APR 69 1423 REPLACES EDITION OF 1 APR 67, WHICH IS OBSOLETE. PAGE ___ OF ___ PAGES

SUPPLEMENTAL INSTRUCTIONS FOR DI-R-1750

This plan will detail the data records, procedures, and reporting formats to be used by the contractor to provide the RIW reports required by this contract.

1. Content: This report shall address the following areas, as a minimum:

Data: The report will identify the basic forms, both government and contractor, that are to be used to collect data.

Processing: The report will identify the data processing steps that will be used to transform the data identified in Data into the required outputs for this contract. The report shall address in detail processing related to calculation of the following parameters:

(a) Contractor turnaround time
(b) achieved MTBF
(c) actual usage rate
(d) warranty price adjustment factors
(e) no trouble found ratio

Formats: The report shall identify the format of other RIW related reports. Sample heading sheets, data listings and supporting narrative shall be included as appropriate to illustrate the selected formats.

SUPPLEMENTAL INSTRUCTIONS TO DI-R-1753

Warranty Data Report Preparation Instructions

Submission of first report will be 15 days after the Initial Anniversary Date (IAD) where the IAD is defined to be the date of successful completion of DTIII Production Verification Testing - Government (PVT-G). Subsequent reports will be delivered semi-annually.

This report shall include, but not be limited to, the following information which describes warranty claim and repair activity.

(a) A serial number record for each Unit under warranty of initial delivery date and most recent date of shipment.

(b) A record by serial number of delivery of each Unit repaired or replaced under the warranty provisions showing dates and Elapsed Time Indicator (ETI) readings at receipt and at reshipment.

(c) An analysis of Unit failure experience including summaries of modes, trends, or patterns of failure in field usage. Recommended or projected action covering corrective action to reduce failures shall also be included.

(d) A detailed record of all Units dispositioned during the preceding report period. This record will include delivery dates, ETI readings at time of previous repair, and at time of disposition. The contractor shall furnish probable cause of damage and suggested actions which the Government should take or which the contractor has taken to preclude similar occurrences.

(e) A tabulation of all Units reported lost or destroyed by serial number including date reported and remaining period of warranty.

(f) A tabulation, by serial number, of all Units replaced by the Contractor and cross referenced to the serial number of the new Units.

(g) A statistical tabulation of manhours and category of labor expended during the report period covering the disposition of returned Units from receipt on dock to reshipment to the Government (for all returns).

(h) An analysis of the average turnaround time for the previous 6 month period.

(i) A statistical tabulation of repair parts and materials costs, together with a summary of most frequently repaired or replaced parts and assemblies.

(j) A complete tabulation of all ECP's submitted and the status of each.

(k) A tabulation by serial number of the configuration of each Unit in the government inventory.

(l) Other pertinent data, facts, or information which would be helpful in the prevention of future failures.

(m) A tabulation by serial number of all Units in the secure storage area.

(n) As required for contract adjustment determinations,

(1) average turnaround time
(2) achieved MTBF
(3) actual usage rate
(4) warranty price adjustment factors
(5) no trouble found ratio

Warranty Effectiveness Study Preparation Instructions

Initial report will be delivered 30 days after the IAD and subsequent reports will be delivered annually.

This report shall include:

(1) A summary of the Contractor's experience and conclusions, if appropriate, regarding the effectiveness of the warranty concept as applied in this contract.

(2) Recommendations and suggestions regarding warranty provisions implementation and administration which may benefit Government and industry in future procurements.

APPENDIX C

SUMMARY OF VISITS AND CONTACTS

The organizations and offices listed below were contacted during this effort.

MERADCOM:

Office of the Project Manager, FAMECE/UET (Family of Military Engineering Construction Equipment/Universal Engineering Tractor)

DoD Project Manager Mobile Electric Power

Marine and Bridge Laboratory

Mechanical and Construction Equipment Laboratory

Product Assurance and Testing Directorate

DARCOM: Directorate for Quality Assurance

AVRADCOM: Directorate for Product Assurance

U.S. Army, 4th Infantry Division (Mechanized):

Logistics (G4)

DARCOM Logistics Assistance Office

4th Supply and Transportation Battalion

52nd Engineering Battalion

TARCOM: Maintenance

Caterpillar Tractor Co., Peoria, Illinois

Clark Equipment Co., Benton Harbor, Michigan

Fermont Division of Dynamics Corporation of America, Bridgeport, Connecticut

Pacific Car and Foundry Corp., Renton, Washington

Solar Turbines International, a division of International Harvester Corp., San Diego, California

The following organizations and offices were contacted during a survey of fixed ground equipment on another contract. However, the information obtained in that survey also contributed to this effort:

COMSAT Maintenance and Supply Center, Clarksville, Maryland

COMSAT Headquarters, Ground Segment Development Division, Washington, D.C.

Farquhar Corporation, Baltimore, Maryland

Foxboro Company, Foxboro, Massachusetts

GTE Satellite Corporation, Stamford, Connecticut

Magnavox Corporation, Alexandria, Virginia

Sales Associates, Washington, D.C.

U.S. Air Force:

678th Radar Squadron, Lake Charles AFS, Louisiana

772nd Radar Squadron, Gibbsborough AFS, New Jersey

Ground Equipment Maintenance Engineering Division, Langley AFB, Virginia

APPENDIX D

USER'S GUIDE FOR LIFE-CYCLE COST MODEL

1. INTRODUCTION

The RIW versus organic maintenance life-cycle cost model used in this investigation was adapted from a model developed for the U.S. Air Force under Contract F30602-77-C-0217 to Rome Air Development Center. This previous model was developed to analyze the application of RIW to Air Force fixed ground electronic systems. This previous model was documented as part of this earlier effort.*

The computer program is written in time-sharing FORTRAN Extended applicable to the Control Data Corporation Network Operating System (NOS). This study was performed via the CYBERNET Services FTNTS subsystem. This program, with minor modifications, can be converted to other time-sharing or batch systems.

Section Two describes the format and requirements for preparing input data. The methodology used to calculate life-cycle cost elements is discussed in Section Three. Section Four provides operating instructions and illustrates the use of the model with a sample run that was used to develop some of the cost information in Section Nine of the text.

2. PREPARATION OF INPUT DATA FILES

The computer program has two forms of inputs: (1) two data files constructed prior to program execution and (2) interactive inputs entered through an interactive terminal. This section describes the former, while the interactive inputs are discussed in Section 4.

The general data file contains labor rates, contractor profit percentages, and training costs. The second file contains equipment-level data, describing the subassembly and modules included within the equipment.

A line of data for either file has the following form:

Line Number   Blank   1st Data Element, 2nd Data Element, etc.

**Guidelines for Application of Warranty-Guarantee to Air Force Ground Electronic Equipment*, ARINC Research Publication 1710-01-1-1996, August 1979.

A sample data line for inputting labor rates of \$10.11, \$11.50, and \$14.00 would be

55 10.11, 11.50, 14.00

where 55 is the line number, and the subsequent numbers are the labor rate data. The line number is a convenience for the user and is ignored by the program, but it cannot be omitted in developing the file. The general and equipment files must be structured as outlined in the following subsections.

2.1 The General Data File

The organization and form of the general data file are shown in Table D-1. These data elements are defined and discussed in the following subsections.

2.1.1 Maintenance Flow Descriptions (Lines 1-4)

In order to calculate maintenance costs and spares costs, it is necessary to determine how failed items are handled. This is done by specifying to the program a series of probabilities that describe the maintenance activity at various levels.

To determine these probabilities, an analyst can use the pipeline flow node chart illustrated in Figure D-1. This chart illustrates the input probabilities for full organic support. The flow chart is constructed from left to right starting with system demands at node 1 . The system demands are divided into two paths. The solid lines represent the flow of subassemblies, and the dashed lines represent the flow of modules.

The node chart is constructed so that all probabilities associated with the flow out of each node must sum to one. For instance, at node 2, POSO and 1 - POSO sum to one. The dashed line that flows from node 1 to node 2 to node 3 and then to node 4 indicates the flow of the module which, due to a repair of subassembly at the GS level, causes an action to be taken on the module. An assumption has been made that for each subassembly repaired at the GS level, a failed module will be generated.

Consider the flow of subassemblies. The probability PSO states that from all the system demands that occur at node 1, a certain percentage (PSO) will require action to be taken on a subassembly. Proceeding to node 2, POSO is the probability that, of all the subassemblies generated from node 1, a certain percentage will be repaired at the organizational/DS levels. The remaining subassemblies continue to node 3, the GS level of maintenance. The following three actions are taken on subassemblies at the GS level:

- The subassemblies can Retest OK (RTOK). This situation is accounted for by the term RTOKS, which is the probability of Retest OK of a subassembly at the Intermediate level.

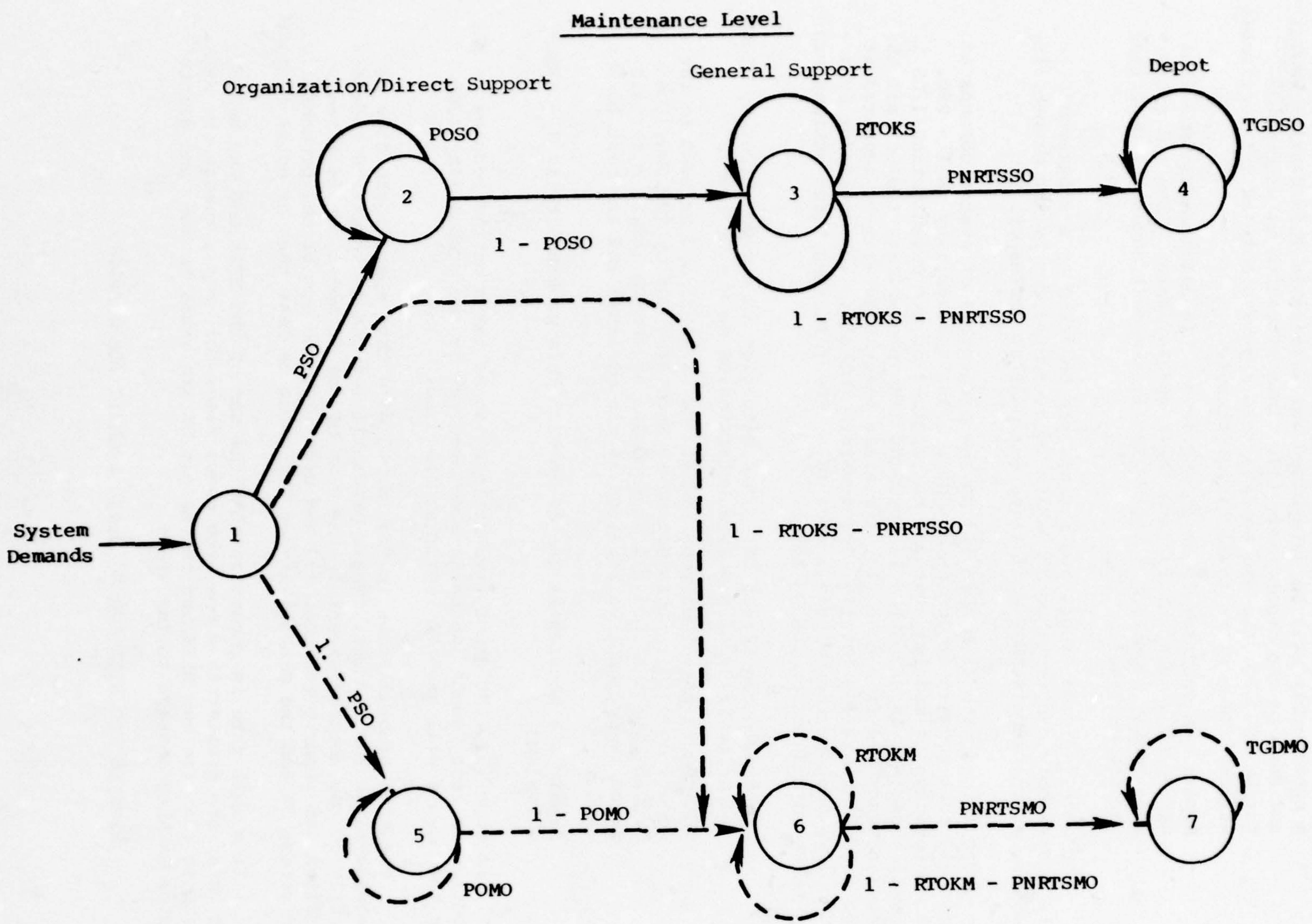

FIGURE D-1
PIPELINE FLOW NODE CHART

- A subassembly will be determined Not Repairable This Station (NRTS) and sent to the depot, node 4. This situation is accounted for by PNRTSSO, the probability that a subassembly is not repairable at the intermediate level of maintenance.
- Repair the subassembly at the GS level. It has been assumed that to repair a subassembly requires a module spare. Thus for every subassembly repaired at the GS level, a module demand is generated for the GS level.

At node 4, the depot, two actions can be taken on a subassembly -- the subassembly can test "good" (which is accounted for by the probability TGDSO), or the subassembly will require repair at the depot.

The second path from node 1 is the percentage of system demands at node 1 that require action on a module. This probability is 1 - PSO. The percentage of modules that can be repaired at the organizational/DS level, node 5, is accounted for by POMO (the probability that of all the modules generated from node 1, a certain percentage will be repaired at the organizational/DS level). The remaining modules, accounted for by 1 - POMO, are sent to the GS level, node 6. The following three actions can be taken on modules at the GS level:

- The module can Retest OK. This situation is accounted for by RTOKM, the probability of a module Retesting OK at the GS level.
- The module cannot be repaired at the GS level and is sent to the depot, node 7. This action is accounted for by PNRTSMO, the probability that, of all the modules at the GS level, a certain percentage cannot be repaired at the GS level and are sent to the depot.
- Repair the modules at the GS level. This probability is 1 - RTOKM - PNRTSMO.

At node 7, the depot, two actions can be taken on the modules -- the module can test "good" (which is accounted for by the probability TGDMO), or the module will require repair at the depot.

The nine probabilities in Figure D-1 will thus specify the flow of subassemblies and modules. These probabilities can be specified independently of one another except in the case of the GS nodes, where three actions can occur. For node 3 and node 6, the sum of the probability of retest OK and the probability of NRTS must be less than or equal to one.

If a NRTS rate is chosen so that the sum of the NRTS and the Retest OK rates are greater than one, the model flags this fact, resets the NRTS rate so that the new NRTS and the Retest OK are equal to one, and prints out a warning message to the user:

NRTS IS TOO HIGH FOR MODULES, ORGANIC (OR WARRANTY)

The nine probabilities that have described the maintenance flow are inputs required for the economic model. Specifically, they are inputs for organic maintenance. A similar set of probabilities is required for warranty. The following is one-for-one comparison of the organic and warranty probability inputs:

Organic	Warranty
PSO	PSW
POSO	POSW
PNRTSSO	PNRTSSW
POMO	POMW
PNRTSMO	PNRTSMW
TGDSO	TDGSW
TGDMO	TDGMW

RTOKS and RTOKM are not included in the above list because it is assumed that the Retest OK probabilities at the GS level are not a function of whether organic or warranty support exist.

Thus far it has been assumed that three levels of maintenance exist -- organizational/DS, GS, and depot. When no distinct intermediate levels of maintenance exist, and there is a user spares supply (i.e., failures are NRTSd directly to the depot from organizational/DS maintenance), the model can account for this situation with the following inputs:

- RTOKS = 0.0
- RTOKM = 0.0
- PNRTSSO = 1.0
- PNRTSMO = 1.0
- PNRTSSW = 1.0
- PNRTSMW = 1.0

These parameter values tell the model to spare at the intermediate level but not to repair at the intermediate level.

To summarize, the definitions of the elements in lines 1-4 of Table D-1 are given below.

PNRTSSO. The probability at the GS level that a subassembly is sent back to the depot for repair under organic maintenance because of Not-Repairable-This-Station determination.

PNRTSSW. The probability at the GS level that a subassembly is sent back to the contractor for repair because of Not-Repairable-This-Station determination when a warranty exists.

TABLE D-1
CONTENTS OF GENERAL DATA FILE

LINE NUMBER	
1	PNRTSSO, PNPTSSW, PNRTSMO, PNRTSMW
2	PSO, PSE, RTOKS, RTOKM
3	POSO, POSW, POMO, POMW
4	TGDSO, TGDSW, TGMO, TGDMW
5	TBRCO, TRBCW, TOSS, TOSM
6	TDRCSO, TRDCSW, TDRCMO, TDRCMW
7	BMORT, VMOD, PUDAF
8	PSUFF, NY, DR
9	CFCMHD, AFCMHD
10	CALRCM
11	AALRCM(1), AALRCM(2), AALRCM(3)
12	CCMML
13	ACMMLO(1), ACMMLO(2), ACMMLO(3)
14	CCMMM
15	ACMMMO(1), ACMMMO(2), ACMMO(3)
16	CFPMMD, AFPMMD
17	CALRPM
18	AALRPM(1), AALRPM(2), AALRPM(3)
19	PMRO(1), PMRO(2), PMRO(3)
20	PMRW(1), PMRW(2), PMRW(3)
21	AGBO, AGBW, AGDO
22	DTAO, DTAW
23	RSK, PFT, DTP, RIWFP, YCOTHW
24	NPCO, NPCW, CIM
25	OTHO, OTHW, OTHWO, YOTHO, YOTHW, CTRANS
26	PCTGW, PCTGO, PLIM, NBX
X*	**NB(K), HM(K), NBY(K)
X	***NSCH (1,K), NSCH(2,K), NSCH(3,K), NSCH(4,K), NSCH(5,K)
X	†NSCH(6,K), NSCH(7,K), NSCH(8,K), NSCH(9,K), NSCH(10,K)
XX††	AFCMHB (1,K), AFCMHB(2,K)
XXX†††	AFPMMB(1,K), AFPMMB(2,K)

*Repeat lines X for each GS type.
**Inputs for K-type GS.
***Five consecutive years of inputs for K-type GS.
†Five more consecutive years of inputs for K-type GS, if any.
††Repeat line XX for each GS type.
†††Repeat line XXX for each GS type.

PNRTSMO. The probability at the GS level that a module is sent back to the depot for repair under organic maintenance because of Not-Repairable-This-Station determination.

PNRTSMW. The probability at the GS level that a module is sent to the contractor for repair because of a Not-Repairable-This-Station determination when a warranty exists.

PSO. The probability that a system demand at the organizational/DS level will require action to be taken on a subassembly under organic maintenance.

PSW. The probability that a system demand at the organizational/DS level will require action to be taken on a subassembly on which a warranty exists.

RTOKS. The probability that a subassembly demand at GS level will result in a Retest OK. This applies to both organic and warranty.

RTOKM. The probability that a module demand at the GS level will result in a Retest OK. This applies to both organic and warranty.

POSO. The probability that a subassembly is repaired at the organizational/DS level under organic maintenance.

POSW. The probability that a subassembly is repaired at the organizational/DS level when a warranty exists.

POMO. The probability that a module is repaired at the organizational/DS level under organic maintenance.

POMW. The probability that a module is repaired at the organizational/DS level when a warranty exists.

TGDSO. The probability that a subassembly sent to the depot will test "good" under organic maintenance.

TGDSW. The probability that a subassembly sent to the contractor will test "good" when a warranty exists.

TGDMO. The probability that a module sent to the depot will test "good" under organic maintenance.

TGDMW. The probability that a module sent to the contractor will test "good" when a warranty exists.

2.1.2 Turnaround Times (Lines 5-6)

These elements describe the average times that materiels spend at and traveling among the nodes in Figure D-1. In all cases, the inputs represent averages across the equipment and across all deployments. The model will allow an analyst to test the sensitivity of the outputs to these parameters.

TBRCO. The base-repair-cycle time in days for organic maintenance, which is an average time. It applied to the following scenarios:

- The time from when an item is removed from the system, taken to the GS level, checked, repaired, and placed in the GS spares pool.
- The time from when an item is removed from the system, taken to the GS level, checked, and a determination made that it is not repairable at the GS level of maintenance.

The assumption has been made that, on the average, each of these scenarios will have the same base-cycle time. It has also been assumed that both subassemblies and modules have the same base-cycle time.

TBRCW. The base-repair-cycle time in days for warranty maintenance; similar to TBRCO.

TOSS. Order and ship time for subassembly in days. This period starts when an item is ordered and ends when the item is received at the GS level.

TOSM. Order and ship time for a module in days. This period starts when an item is ordered and ends when the item is received at the GS level.

TDRCSO. The depot-repair-cycle time in days under organic maintenance for a subassembly. This period applies to items that must be sent to the depot for repair. The period starts when the subassembly enters base check-out and includes the base-repair-cycle time, transportation to depot, repair at depot, and placement into depot stock.

TDRCSW. The depot-repair-cycle time for a subassembly in days when a warranty exists. The period is the same as for TDRCSO.

TDRCMO. The depot-repair-cycle time for a module in days under organic maintenance. This period is the same as for TDRCSO.

TDRCMW. The depot-repair-cycle time for a module in days when a warranty exists. This period is the same for TDRCSO.

2.1.3 Warranty to Organic Transition Data (Line 7)

The following elements are used to describe how the value of spares, originally used to support an equipment under warranty, will be handled in the model when a transition to organic maintenance occurs.

BMORT. The depreciation factor for determining the value of excess subassemblies at time of transition from warranty to organic maintenance. The equation for this value is CL × (1 - TW/NY) × BMORT, where CL is the subassembly cost, TW is the warranty period, and NY is the number of life-cycle years being considered. If BMORT is equal to 1.0, linear depreciation results. For example, if the warranty period is four years and the life-cycle period is 10 years, each excess subassembly is valued at

CL × (1 - 4/10) = 0.6 CL. A value of BMORT less than 1 implies that a subassembly depreciates faster than linear depreciation, while a value of BMORT greater than 1 implies slower-than-linear depreciation.

VMOD. The depreciation factor for determining the value of excess modules at the time of transition from warranty to organic maintenance. This parameter is BMORT's counterpart for modules.

PUDAF. The fraction of required discard-at-failure modules available at transition that will be used for future organic maintenance. After disassembly of excess subassemblies that were used as spares under warranty, a number of discard-at-failure modules may be available that could be used for meeting future replacement requirements. However, not all of these modules may see service because of losses occurring in disassembly, shipping, handling, and inventory control.

A worst case situation for warranty occurs when each of these parameters is set to 0.0. This figure assumes no salvage value in future use of extra materiel available during transition.

2.1.4 Sufficiency, Useful Life, and Discount Rate (Line 8)

This line identifies several factors used in the analysis.

PSUFF. Spares sufficiency probability. The steady-state probability that a spare will be available when required.

NY. The number of life-cycle years under consideration. Generally NY presents the expected useful life of the equipment but may be any selected time period.

DR. The annual discount rate. Use of a discount rate (typically 0.10) translates all future dollar expenditures to a present-value basis. A value of DR = 0 can be used for analysis without discounting.

2.1.5 Repair Times and Labor Rates (Lines 9-20)

These elements describe the man-hours required to perform maintenance actions at the various nodes of Figure D-1 and the average labor rates associated with various types of activity.

CFCMHD. The contractor's average minimum corrective maintenance man-hours per month for repairs. This is a fixed level of effort that can be considered independent of the demands of the system. The model compares this value with a demand-driven value and selects the larger of the two. This parameter can be set equal to zero if no fixed manpower has been allocated to corrective maintenance.

AFCMHD. The Army's average minimum corrective maintenance man-hours per month for the depot. This is a fixed level of effort that can be considered independent of the demands of the system. The model compares this

value with a demand-driven value and selects the larger of the two. This parameter can be set equal to zero if no fixed manpower has been allocated to corrective maintenance.

CALRCM. The contractor's average labor rate in dollars per man-hour for corrective maintenance.

AALRCM(1), (2), (3).* The Army average labor rate in dollars per man-hour for corrective maintenance for the three maintenance levels.

CCMML. The contractor's average corrective maintenance man-hours for a subassembly action.

ACMMLO(1), (2), (3).* The Army average corrective maintenance man-hours for a subassembly action for each of the three maintenance levels under organic maintenance.

CCMMM. The contractor's average corrective maintenance man-hours for a module action.

ACMMMO(1), (2), (3).* The Army average corrective maintenance man-hours for a module action for each of three maintenance levels under organic maintenance.

CFPMMD. The contractor's average minimum preventive maintenance man-hours per month for the RIW. This is a fixed level of effort that can be considered independent of the demands of the system. The model compares this value with a demand-driven value and selects the larger of the two. This parameter can be set equal to zero if no fixed manpower is allocated to preventive maintenance.

AFPMMD. The Army's average preventive maintenance man-hours per month for the depot. This parameter is the counterpart to CFPMMD, and it can be set equal to zero if no fixed manpower is allocated to preventive maintenance.

CALRPM. The contractor's average labor rate in dollars per man-hour for preventive maintenance.

AALRPM(1), (2), (3).* The Army average labor rate in dollars per man-hours for preventive maintenance for the three maintenance levels.

PMRO(1), (2), (3).* Man-hours of preventive maintenance per operate hour on the system for each maintenance level under organic maintenance.

PMRW(1), (2), (3).* Man-hours of preventive maintenance per operate hour on the system for each maintenance level when a warranty is in existence.

---

*Three levels; 1 = Organization/DS, 2 = GS, 3 = Depot.

2.1.6 Test Equipment (Line 21)

These elements address test equipment costs.

AGBO. Acquisition cost of test equipment (organic maintenance). The cost per GS to purchase the GS and DS test equipment necessary to support the installed equipment under organic maintenance.

AGBW. Acquisition cost of test equipment (warranty). The cost per GS to purchase GS and DS test equipment necessary to support the installed equipment while it is under warranty. Generally, AGBW will be less than AGBO because test equipment under warranty usually will involve a simple Go/No-Go test, while such equipment under organic maintenance may also include the capability for fault diagnosis to the module level.

AGDO. Acquisition cost of depot test equipment (organic maintenance). The cost to purchase test equipment for depot maintenance.

2.1.7 Data (Line 22)

These elements identify the data costs of the procurement.

DTAO. Data cost (organic maintenance). The cost to acquire all pertinent and identifiable data associated with acquisition under organic maintenance.

DTAW. Data cost (warranty). The cost to acquire all pertinent and identifiable data associated with acquisition under a warranty. Additional costs for data required at transition are covered in Line 25.

2.1.8 RIW Pricing Data (Line 23)

The following elements are used in estimating the contractor's RIW price, if no bid price is available.

RSK. Contractor warranty yearly risk factor. This fraction is applied to all estimated warranty costs to cover contractor risks in warranty pricing. The risk factor for a warranty of TW years is calculated as a compounded rate equal to $(1 + \mathrm{RSK})^{\mathrm{TW}}$. If a bid price is used, RSK is set equal to zero.

PFT. Contractor warranty profit factor. This fraction is applied to all estimated warranty costs to cover the contractor's warranty profit. Total warranty profit is equal to Warranty Cost × PFT. If a bid price is used, PFT is set equal to zero.

DTP. Factor for data and other warranty costs. The multiplier factor to be applied to all estimated warranty costs to include the contractor's data costs, administrative costs, and other costs related to performing warranty services. (See COTHW and YCOTHW for alternative inputs to cover "other" contractor costs). DTP can be set equal to zero if a warranty bid price is to be used.

RIWFP. Contractor fixed cost, i.e., fixed cost that is not included in overhead. If a contractor gives a bid price, RIWFP is the bid price and RSK must be set equal to zero.

YCOTHW. Contractor other yearly cost (warranty). Yearly cost for performing warranty activity that are not included elsewhere.

2.1.9 Inventory Management (Line 24)

These elements are used to estimate inventory management costs.

NPCO. Number of P-coded items (organic maintenance). The number of new P-coded or FSN items to be introduced into the inventory under organic maintenance.

NPCW. Number of P-coded items (warranty). The number of new P-coded or FSN items to be introduced into the inventory under warranty.

CIM. Annual inventory management cost. The yearly cost for inventory management of each new P-coded item in the inventory.

2.1.10 Other Costs (Line 25)

These elements allow the analyst to input other costs that have not been covered by the earlier inputs.

OTHO. Other costs (organic maintenance). All other costs incurred under organic maintenance at the time of equipment acquisition.

OTHW. Other costs (full warranty). All other costs incurred under a full warranty at the time of equipment acquisition.

OTHWO. Other costs (warranty/organic). All other costs incurred under a warranty/organic maintenance concept at the time of equipment acquisition.

YOTHO. Yearly other costs (organic maintenance). Yearly costs under organic maintenance not included in any other category.

YOTHW. Yearly other costs (warranty). Yearly costs under a warranty that are not included in any other category.

CTRANS. Costs of transition. Costs incurred at the time of transition from warranty to organic maintenance that are not included in any other category.

These cost elements provide an analyst with an opportunity to incorporate specific costs that may not be treated in appropriate depth elsewhere in the model. For example, transportation costs for corrective maintenance are not a part of the model. If an analyst feels that transportation cost differences could affect a decision, these calculation could be done off-line using average MTBF estimates output by the model

and average transportation costs for organic and warranty support. The results could then be reinserted in the model as part of YOTHO and YOTHW. Future runs would then reflect this analysis.

2.1.11 Reliability Growth and GS structure (Line 26)

These elements describe the reliability growth (or decay) characteristics of the population and identify the upper (or lower) limits of MTBF that may be achieved.

PCTGW. The percentage of growth (or decay) in MTBF between 1,000 and 50,000 hours of operation for a system under warranty (i.e., if the growth is considered to be 10 percent of the initial MTBF, then enter 0.10). MTBF decay is represented by negative values (e.g., -0.10).

PCTGO. The percentage of growth (or decay) in MTBF between 1,000 and 50,000 hours of operation for a system under organic maintenance (similar to PCTGW). MTBF decay is also represented by negative numbers.

PLIM. The ultimate growth (or decay) of MTBF for both organic and warranty. This parameter is entered as a percentage increase (i.e., if the ultimate decay is considered to be 20 percent of the initial MTBF, then enter -0.20).

NBX. The number of different GS types. The sparing algorithms calculate demands at GS and depot in order to identify spares requirements. Thus the equipment deployment data must be structured to reflect impacts at the GS level. A single GS type has commonality of quantity deployed per GS and usage rate per equipment. Two examples will illustrate this concept:

(1) Early in an equipment's life cycle the following data might be available: 200 systems will be bought, they will operate an average of 150 hours per month, and they will be supported through 50 GS organizations. At this level of detail a single "average GS" type can be developed which has:

4 systems per GS

150 operating hours per month per system

(2) When greater detail on deployment is available, additional GS types may be identified. If, in the above case, it develops that 60 GSs will support three systems each with an average operating time of 160 hours per month, and 20 GSs will each support one system with an average operating time of 80 hours per month, then this is reflected by establishing 2 GS types:

type 1: Three systems per GS with 160 hours per month

type 2: One system per GS with 80 hours per month

This latter case is used later in this appendix in the sample run.

2.1.12 Deployment Data (Line X)

For each GS type a set of data lines numbered X in Table D-1 must be entered. These elements contain the following data.

NB(K). The number of systems per GS for GS type K.

HM(K). Operating hours per month per system for GS type K.

NBY(K). The number of years over which the deployments will be made for GS type K.

NSCH(J,K). The number of systems activated on a yearly basis for GS type K. These inputs must be entered in five consecutive-year intervals (i.e., J = 1 through 5, J = 6 through 10, etc.) For each line of data, all five entries are required; i.e., zeros must be input to fill out the line.

2.1.13 Fixed Levels of Corrective Maintenance (Line XX)

These elements allow the analyst to specify fixed minimum manpower levels for corrective maintenance, if applicable. One line of input is required for each of the NBX GS types.

AFCMHB(1,K). The Army's minimum fixed corrective maintenance man-hours for organizational and DS level maintenance per month per GS type K. These data represent a fixed level of effort that can be considered to be independent of the demands of the system. This value is compared with a calculated demand-driven corrective maintenance in the model, and the larger value is chosen. If a fixed manpower loading is not planned, the parameter is set to zero. This parameter is entered for each type of base.

AFCMHB(2,K). The Army's minimum fixed corrective maintenance man-hours for GS level maintenance per month per GS type K. This parameter has the same constraints as AFCMHB(1,K).

2.1.14 Fixed Levels of Preventive Maintenance (Line XXX)

As in Subsection 2.1.13, the analyst can specify fixed minimum levels of preventive maintenance, if applicable. One line is required for each of the NBX GS types.

AFPMMB(1,K). The Army's fixed preventive maintenance man-hours for the organizational and DS level maintenance per month per GS type K. This fixed input is considered a minimum value regardless of the demands of the system. This value is compared with a calculated demand-driven preventive maintenance in the model, and the larger value is chosen. If a fixed manpower loading is not planned, this parameter is set equal to zero. This parameter is entered for each type of base.

AFPMMB(2,K). The Army's preventive maintenance man-hours for GS level maintenance per month per GS type K. This parameter has the same constraints as CFPMMB(1,K).

2.2 The Equipment Data File

The organization and form of the Equipment Data File are shown in Table D-2. These data elements are defined and discussed in the following sections.

TABLE D-2
CONTENTS OF EQUIPMENT DATA FILE

LINE NUMBER		
1	NLRU	
2	FUELO, FUELW, OVERO, OVERW, HBO, INTOV	
	For Subassembly 1 through NLRU	
Sub 1	NMOD(J), CCL(J), CLW(J), TSP(J)	
2	CINSO(J), CINSW(J)	For jth subassembly
	For Modules 1 through NMOD(J)	
MOD 1	NQ(1,J), XBF(1,J), IDF(1,J), C(1,J)	1st module in jth subassembly
	NQ(2,J), XBF(2,J), IDF(2,J), C(2,J)	2nd module in jth subassembly, etc.

2.2.1 Equipment Level Data (Lines 1-2)

These elements identify the number of LRUs in the equipment and the energy and overhaul costs associated with the equipment.

NLRU. The number of subassemblies in the equipment. Each subassembly is counted separately, even if two are identical.

FUELO. The energy cost in dollars per system operating hour under organic maintenance.

FUELW. The energy cost in dollars per system operating hour under warranty.

OVERO. The overhaul cost in dollars for a system under organic maintenance. This cost includes transportation to and from overhaul site.

OVERW. The overhaul cost in dollars for a system under warranty. This cost includes transportation to and from overhaul site.

HBO. The number of system operating hours between overhauls.

INTOV. The number of years between system overhauls. During program operation, the computer asks the analyst to identify whether overhauls are based on operating hours or years. However, both elements must be present in the input file. A zero can be used for a non-applicable element.

2.2.2 Subassembly Data (Lines Sub 1-2)

The program uses NLRU to determine how much subassembly data will be read in. For each subassembly, the following data elements are required.

- NMOD(J). The number of module types in the jth subassembly. Two or more identical modules in a subassembly are counted as one module type. If there are no modules in the subassembly, set NMOD(J) equal to 1 and complete the required module data, treating the subassembly as a module.
- CL(J). The acquisition cost of a spare jth subassembly (organic maintenance). This is the average cost of purchasing a spare jth unit. [Note: If there are no modules in the subassembly, set CL(J) equal to zero].
- CLW(J). The acquisition cost of a spare jth subassembly (warranty). If CL(J) is zero, then CLW(J) is also zero for the "no module" case.
- TSP(J). This variable is not used in this program. Set TSP(J) equal to zero.
- CINSO(J). Initial acquisition cost of jth type subassembly (organic maintenance.
- CINSW(J). Initial acquisition cost of jth type subassembly (warranty).

2.2.3 Module Data (Lines MOD 1)

The data for each subassembly (Lines Sub 1-2) in the file are followed by the data for all modules in that subassembly.

NQ(I,J). Module quantity. This data element is the number of modules of the i^{th} type in the j^{th} subassembly.

XBF(I,J). Initial module MTBF (organic maintenance). The MTBF of the i^{th} type module in the j^{th} subassembly before any MTBF growth factors are introduced.

IDF(I,J). Module repair code. If the i^{th} module in the j^{th} subassembly is classified as expendable (e.g., discard-at-failure, throwaway, etc.), IDF(I,J) is equal to 0 . If repairable, set IDF(I,J) equal to 1.

C(I,J). Module cost. The average acquisition cost for the i^{th} module in the j^{th} subassembly.

3. COST CALCULATION FEATURES

The basic LCC categories addressed by the model are presented and defined in Section 8 of the text. This subsection will summarize the methodology used to develop these cost estimates.

3.1 Acquisition Cost

It is assumed that all systems are paid for in the first year of deployment. No discounting is applied to this figure, which represents the base year of the cost calculation. Acquisition cost is computed as the product of the quantity of systems identified in the deployment schedule times acquisition cost.

3.2 Initial Spares

Initial spares costs are developed by calculating the maximum demand rates for each module and subassembly under either an organic or warranty/organic support alternative. Then the program calculates the spares necessary to meet each demand rate and multiplies this value by the unit cost of the item being spared. During transition from warranty to organic, there is generally an excess of spare subassemblies, since these were the only class of spares available under RIW. The program assumes that at transition, excess spare subassemblies can be disassembled and used as repairable module spares and that any remaining module spares requirements will require additional purchases. Input elements in the general data file identify the residual value that any excess subassemblies or modules may have at transition.

Two important features of the methodology for calculating initial spares cost are the use of a reliability growth model to allow for other than constant failure rate over the life of the equipment and the spares calculation model. These features are discussed in the following sections.

3.2.1 Reliability Growth Model

The growth model used in this program was developed by J.T. Duane*, who reported that the instantaneous MTBF of equipment has the form

$$\theta(T) = \frac{AT^{\beta}}{(1-\beta)} \qquad \text{(D-1)}$$

where $\theta(T)$ = the instantaneous MTBF after T operating hours
A = a scale factor
β = the growth rate

On a log-log plot equation D-1 is a straight line since

$$\ln \theta(T) = \ln A/(1-\beta) + \beta \ln T \qquad \text{(D-2)}$$

*Codier, E.O., "Reliability Growth in Real Life", Proceedings of the 1968 Annual Symposium of Reliability, Boston, Massachusetts, January 1968, pp. 458-469.

This program uses this representation of reliability growth with two added features:

- Negative growth inputs are allowed which can represent decay in population MTBF.
- An input is used to set an upper limit to MTBF growth (or a lower limit to decay). Without such limits, the MTBF (see Equation D-1) is unbounded or, conversely, can come arbitrarily close to zero.

Figure D-2(a) shows the situation for simple organic growth. Module MTBFs, input to the equipment file, represent the MTBF expected at 1,000 population hours of operation. The general data file contains the percent MTBF growth expected over the interval 1,000 to 50,000 population operate hours. This is shown in Figure D-2(a) as p percent. The instantaneous MTBF line passes through the points (1000,X) and [50000, (1+p)X]. The general file also contains a maximum percent MTBF growth (q), which sets the maximum MTBF at (1+q) × MTBF at 1,000 hours.

Figure D-2(b) shows MTBF decay with time. In this case, p and q each have negative signs. If zero growth is desired, p is set to zero and the sign and value of q is not important.

For each year of the analysis, the program calculates population operate hours at the beginning and end of the year. The program then integrates over MTBF curves similar to those shown in Figures D-2(a) or (b) to calculate the average MTBF for the year. This average is used to calculate maintenance demands and to estimate spares demands for the year.

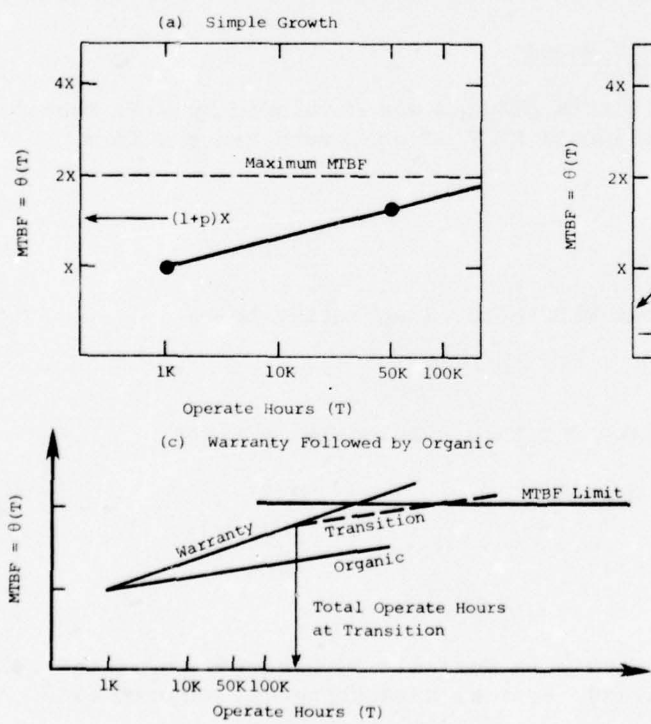

FIGURE D-2
GROWTH MODELS FOR MTBF

Figure D-2(c) shows the situation when warranty is in effect. Now there are two growth curves (one for warranty, and one for organic) and, when both curves have positive growth, an upper-limit MTBF. During each year of warranty, the program integrates along the warranty growth curve to calculate average MTBF for the year. After transition, the program calculates annual MTBF by integrating along the dotted line, which is the organic growth rate line translated to reflect the MTBF achieved at the end of warranty. The program contains sufficient bookkeeping logic to stop MTBF growth and continue along the MTBF limit line whenever that line is reached.

Table D-3 shows the admissible combinations of growth/decay and the type of MTBF limit to be specified.

TABLE D-3
ADMISSIBLE GROWTH AND MTBF LIMIT COMBINATIONS

Warranty Growth	Organic Growth	MTBF Limit
positive	positive or zero	upper
zero	zero or negative	lower
negative	negative	lower

3.2.2 Spares Calculation Methodology

Two sparing algorithms are used in this program: a Poisson process and fractional sparing. The choice between the two algorithms is made by comparing the pipeline demand product (i.e., D demands per day × P days in the pipeline) at each GS type, to a preset value of 1.5 items. If this product is less than or equal to 1.5 items, the fractional sparing algorithm computes the spares for the GS type. If the product is greater than 1.5 items, the Poisson sparing algorithm is utilized. Fractional sparing has been introduced to eliminate high costs of sparing at a GS (which may be a consequence of the low demand levels often observed there).

3.2.2.1 Fractional Sparing

The fractional sparing algorithm considers the pipeline demand product per GS type. To compute all the spares for GS type K, a single spare for the depot is added to the total of fractional demands for this GS type. This value is then fed to the main program, which sums the contributions for each GS type and then rounds up to the next whole number of spares.

3.2.2.2 Poisson Sparing

When the pipeline demand product exceeds 1.5 items, it is assumed that demands follow a Poisson process. If the maintenance demand rate is D per day for items from a spares pool and if the average pipeline time to replenish the spares pool is P days, then the number of spares required to meet a

spares-sufficiency level, PSUFF, for a steady-state condition is the smallest integer value of S that satisfies the formula

$$\sum_{n=0}^{S} \frac{e^{-(P \times D)}(P \times D)^n}{n!} \geq PSUFF$$

The program is designed to minimize the total spares requirement under the Poisson assumption; this action is accomplished in the following manner: After calculating initial spares demand at a GS type, the program sets one spare at depot and adjusts pipeline times to reflect a depot delay increment if a spare is not available at GS. Using the new pipeline times, the spares level is recalculated at a GS. Then two spares are set at the depot, pipeline times are adjusted, and this loop on depot-level spares is continued until a minimum spares value is identified. At that point, the spares requirements are made available for other calculations.

3.3 Replenishment Spares

For full organic maintenance, the program calculates the total number of demands for each type of DAF module, multiplies by the replacement cost of that type, and discounts this by the average discount rate over the useful life of the system. The resulting costs are summed over all DAF modules to obtain the organic cost estimate.

For the warranty/organic case, the demands for each DAF module before and after transition are calculated. These figures are multiplied by replacement costs and by the average discount rates before and after transition. For each module, the value of DAF modules available after warranty (because of the breaking down of excess system spares available at this time) is subtracted from these costs. The results are summed over all module types to obtain the warranty/organic cost estimates.

3.3 Corrective Maintenance

For each support alternative, the program calculates the expected corrective maintenance actions at organization/DS, GS, and (when not under warranty) depot for each year of the equipment's useful life. These demands are then multiplied by the average costs to perform such maintenance. The full organic costs, or costs before and after transition, are then discounted using an appropriate average discount rate.

This figure, based on demands, is compared with a second cost, which is based on inputs that identify a fixed amount of man-hours committed to perform corrective maintenance independent of demand rates. The larger of these two costs is selected as the corrective maintenance cost.

3.4 Preventive Maintenance

For each support alternative, the program uses input data to estimate the expected preventive maintenance man-hours at the various maintenance

levels for each year of the equipment's useful life. These demands are then multiplied by appropriate average cost factors and discount rates.

This figure, based on demands, is compared with a second cost, which is based on inputs that identify a fixed amount of man-hours committed to perform preventive maintenance independent of demand rates. The larger of these two costs is selected as preventive maintenance cost.

3.6 Warranty Price

If it is available, the analyst may input a warranty bid price. Otherwise, the warranty price calculations use the generic form shown in Figure D-3. The factors identified in the equations are discussed in the following subsections.

Warranty Price = [(Fixed Direct Costs) + (Other Yearly Costs)(Number of Years)
(Discount Factor) + (Corrective Maintenance Cost
+ Preventive Maintenance Costs)(Discount Factor)
(Factor for data and administrative costs)] × (Risk factor)
(Profit Factor)

FIGURE D-3
WARRANTY PRICE EQUATION

3.6.1 Fixed Direct-Costs

Fixed direct-costs represent those special facilities and equipment which will be required to implement the warranty, but will not be included as part of overhead in the labor-rate data input. This cost element will be zero in many cases, if all such fixed costs are included in the overhead factor for labor rate.

3.6.2 Other Yearly Costs

This factor includes recurring costs in other categories. The following are examples:

- Warranty-data report costs
- Test equipment support costs
- Technician training costs
- Bonded storeroom costs
- Module sparing costs

3.6.3 Discount Factor

A significant portion of the contractor's expenditure for warranty occurs in the future, while his payment is generally made at the time of first

delivery of equipment. Therefore, discounting is necessary for present-value analyses. All but fixed direct costs are discounted.

3.6.4 Corrective and Preventive Maintenance Costs

These costs are computed on the basis of system demands, input labor rates, and inputs that identify fixed man-hours committed to corrective and preventive maintenance tasks. The larger of the two costs for each cost category is selected in developing the warranty price.

3.6.5 Data and Administrative Costs

Warranty data and administration costs include the variable contractor costs associated with administering the warranty, as well as the costs of activities associated with data collection analysis. A simple estimate is used for this cost factor: the total warranty repair costs are multiplied by a constant factor to yield a cost that is adjusted for warranty data and administration costs.

3.6.6 Risk Factor

The risk factor is a single parameter incorporating the risk costs associated with the warranty. Rather than consider risk values for each of the cost elements, it is assumed that the contractor prices the warranty by using best estimates and then adjusting this price by a risk factor or (equivalently) by higher profit factor. This simpler approach is used in the model. The risk factor (RSF) has the following form if the warranty period is T_W years:

$$RSF = (1 + RSK)^{T_W}$$

where RSK is an input risk factor for a one-year period expressed as a decimal.

It is noted that as the warranty period increased, the risk factor increased for all RSK>0. The risk factor has a compound-interest form, so that the risk per year of warranty increases as the warranty period increases.

3.6.7 Profit Factor

The profit factor represents the usual percentage of profit normally applied to Government contracts. In actual practice, the contractor may combine the profit and risk factors. However, these factors are separated in Figure D-2 to show the two separate factors that affect price; this separation also simplifies sensitivity analysis.

3.7 AGE

This category represents test equipment costs across all levels of maintenance for the organic support alternative. It calculates the test equipment costs needed to support the equipment under warranty and adds

any incremental test equipment costs at transition. Those latter costs are discounted to reflect the delay in test equipment commitment caused by the warranty.

3.8 Energy

For each year of the equipment's useful life, the program calculates the equipment operate hours for the year. This figure is then multiplied by the input energy cost per hour under warranty or organic and this product is discounted. These annual costs are then summed to develop cost estimates for this category.

3.9 Overhaul

Overhaul costs can be calculated on the basis of equipment operating rates or calendar time. In either case, overhaul demands are calculated by reviewing each deployment year for each GS type. For all equipment deployed to a specific GS type, the program (on the basis of operating rates of the GS type or calendar time, as appropriate) identifies the year or years when those equipments are due for overhaul. After the entire deployment schedule has been reviewed, the program accumulates overhaul demands on an annual basis, multiplies them by the appropriate cost factor (depending on whether or not the equipment is under warranty), and discounts the resulting costs to produce overhaul costs.

3.10 Data

The data costs are either throughput directly or throughput after discounting to reflect costs accrued at transition.

3.11 Inventory Management

Inventory management costs are developed by multiplying (for each year of useful life) the number of items by the cost of management of those items. These costs are discounted to reflect differences in the spending profiles in this category, since certain item costs are deferred under warranty.

3.12 Other

These costs are summed on an annual or one-time basis, depending on the category. Discounting is applied to reflect differences in cost profiles between support alternatives.

4. OPERATING INSTRUCTIONS AND SAMPLE RUN

This section contains a step-by-step explanation of the operation of the organic versus warranty life-cycle-cost model. The sample run, included in the explanation, illustrates some of the user options and serves as a guide for model operation.

The example uses data associated with the MEP-115A 60 kW generator that was discussed in Section Nine of the text. The source code version of the program is MERAD; the object code version is BMERAD.

4.1 Getting Started

The user must prepare two data files that describe both the equipment and the maintenance system. Subsection 2 of this appendix contains a detailed discussion of the data preparation process. In the example, the general data file is GFMEP and the equipment data file EQFMEP.

After the user has signed on at the interactive terminal, he may execute the program in one of two ways: he may compile the source code and execute it, or he may use the object code (if it exists) and execute it by using batch mode. The procedure for each method is slightly different. In the former case, the user enters the following series of commands:

```
FTNTS,OLD,MERAD  CR *
GET,TAPE1 = GFMET  CR
GET,TAPE2 = EQFMET  CR
RUN  CR
```

After each command, the system will respond with "Ready". In the latter case, the user follows the sequence outlined in the following figure:

1. Type in: Batch CR
2. The computer will respond with a "/"
3. This is a prompt for the user. Type in: GET,BMERAD CR
4. The computer will respond with another "/". Type in: GET,TAPE1 = GFMEP CR
5. The computer will respond with another "/". Type in GET,TAPE2 = EQFMEP CR
6. The computer will respond with another "/". Type in BMERAD CR

FIGURE D-4
SEQUENCE TO EXECUTE THE COMPUTER PROGRAM IN BATCH MODE

The batch mode offers lower costs per execution and should be considered if the user intends to perform many analyses.

The example illustrates the batch mode execution sequence (see A in Figure D-5).

---

*Symbol CR denotes striking the carriage return key, making entry shown.

FIGURE D-5
SAMPLE COMPUTER OUTPUT

A


```
BATCH
$RFL,20000.
/GET,BMERAD
/GET,TAPE1=GFMEP
/GET,TAPE2=EQFMEP
/BMERAD
        WARRANTY LCC ANALYSIS

  FILES CALLED? 0 FOR NO, 1 FOR YES
? 1
  DO YOU WANT GENERAL DATA FILE PRINTED, 1-YES, 0-NO
? 1
  DO YOU WANT EQUIPMENT DATA FILE PRINTED, 1-YES, 0-NO
? 1

   *GENERAL DATA FILE*
   10    0.0000     0.0000      .9000      .9000
   20    0.0000     0.0000     0.0000      .1000
   30    0.0000     0.0000      .9000      .9000
   40    0.0000     0.0000      .1000      .1000
   50     40.00      30.00      30.00      30.00
   60     60.00      45.00      60.00      45.00
   70    1.0000     0.0000     0.0000
   75    .90000         10     .10000
   80        0.         0.
   90     31.00
  100     17.00      17.00      35.00
  110   20.0000
  120    5.0000    10.0000    25.0000
  130   20.0000
  140    5.0000    10.0000    25.0000
  150        0.         0.
  160     31.00
  170     17.00      17.00      35.00
  180     .0300     0.0000     0.0000
  190     .0300     0.0000     0.0000
  200     2000.      1000.     75000.
  210    50000.     10000.
  220    .05000     .12000     .05000     50000.     10000.
  230       200         10       300.
  240        0.         0.         0.         0.         0.     40000.
  250   0.00000    0.00000    0.00000          2
  260         3     160.00          2
  270        30         30          0          0          0
  280         1      80.00          2
  290        10         10          0          0          0
  300        0.         0.
  310        0.         0.
  320        0.         0.
  330        0.         0.
```

B

(continued)

FIGURE D-5
(continued)

```
 *EQUIPMENT DATA*
  10          2
  50    3.00000    3.000001700.000001500.000003000.00000          4
 100          1         0.            0.    0.00000
 110    11000.    11000.
 120          1      2000.            1     11000.
 200          1         0.            0.    0.00000
 210     6000.     6000.
 220          1       666.            1      6000.

INITIAL SYSTEM MTBF=  499.6  INITIAL ORGANIC SYSTEM MTBD=  490.1

 ORGANIC FALSE PULL RATE= .019

SYSTEM COST-ORGANIC,WARRANTY = $  17000.  17000.
```

ⓒ

```
     INITIAL     COST PER SPARE SUB
 SUB   MTBF      ORG.    WRNTY.
  1   2000.0       0.       0.
  2    666.0       0.       0.


   OPERATING HOURS AND INSTALL SCHEDULE BY YEAR FOR EACH BASE TYPE
 BASE   # OF   OP HR     ACTIVATED SITES AFTER N YEARS
 TYPE   SETS   PER MO    1      2      3      4      5      6
   1      3    160.     30     30      0      0      0      0
   2      1     80.     10     10      0      0      0      0

  PRINT CODE
? 1
```

ⓓ

```
TOT.# INSTALLS =  200  TOT.OPER.HRS. =      3283200.


 ORGANIC MTBF GROWTH

 1 499.6249062266
 2 499.6249062266
 3 499.6249062266
 4 499.6249062266
 5 499.6249062266
 6 499.6249062266
 7 499.6249062266
 8 499.6249062266
 9 499.6249062266
 10 499.6249062266

AVERAGE ORGANIC GROWTH MTBF =  499.6
```

(continued)

FIGURE D-5
(continued)


```
  ORGANIC MAINTENANCE SPARES
 SUB    SPARES    PCT.       COST
  1        0      0.00          0.
  2        0      0.00          0.

 MODULE SPARES
 SUB   MOD    QTY    SPARES    PCT.
  1     1      1         9     4.50
  2     1      1        19     9.50

TOTAL COST OF SPARE SUBS =          $       0.
TOTAL COST OF SPARE REP.MODULES=  $ 213000.
TOTAL COST OF DAF MODULES =         $       0.

TOTAL SPARES & DAF MODULE COST=   $ 213000.

 WARRANTY PERIODS-TW,DEL,NP
? 1,1,10
 OVERHAUL BASIS: 1 FOR OPERATING HOURS, 2 FOR YEARS   E
? 1


 *** WARRANTY AT DEPOT LEVEL ***


TOTAL ORGANIC LCC = $ 13147208.

WRNTY YRS.        WRNTY LCC    SAVINGS/LOSS   WRNTY   PRICE   AVG.MTBF
   1.00           13167217.       -20009.          82237.       500.
   2.00           13096983.        50225.         132057.       500.
   3.00           13038268.       108940.         193429.       500.
   4.00           12985041.       162167.         255379.       500.
   5.00           12931284.       215925.         318051.       500.   F
   6.00           12900817.       246392.         381588.       500.
   7.00           12878831.       268378.         446137.       500.
   8.00           12857065.       290143.         511847.       500.
   9.00           12853461.       293748.         578069.       500.
  10.00           12845755.       301453.         647359.       500.
FULL W            12755152.       392056.
 INPUT CODE
? 0
 WARRANTY PERIODS-TW,DEL,NP
? 4,0,0
 OVERHAUL BASIS: 1 FOR OPERATING HOURS, 2 FOR YEARS    G
? 1


 *** WARRANTY AT DEPOT LEVEL ***
```

(continued)

FIGURE D-5
(continued)

```
WARRANTY/ORGANIC MTBF GROWTH

 1 499.6249062266
 2 499.6249062265
 3 499.6249062266
 4 499.6249062266
 --TRANSITION--
 5 499.6249062266
 6 499.6249062266
 7 499.6249062266
 8 499.6249062266
 9 499.6249062266
 10 499.6249062265

 INITIAL WARRANTY SYSTEM MTBD=  490.1
 WARRANTY FALSE PULL RATE= .019


WARRANTY SPARES
 SUB   SPARES    PCT.     COST
  1         0    0.00        0.
  2         0    0.00        0.

 DO YOU WANT MODULE SPARES DATA PRINTED, 1-YES, 0-NO     (H)
? 1

 MODULE SPARES
 SUB  MOD   QTY    SPARES    PCT.
  1    1     1         8     4.00
  2    1     1        16     8.00

 WARRANTY SPARES COSTS
                  SUB      REP.MOD.    DAF MOD.     TOTAL
REQUIRED           0.      203807.          0.    203807.
VALUE              0.           0.          0.         0.
NET COST           0.      203807.          0.    203807.

    DISCOUNT FACTORS
DISC1,DSCTW,DSC2,DSCTOT  .8311  .6830  .5200  .6444


 4.0 YEAR WARRANTY PRICE            255379.
PCT/YR PER INSTALLED SET     1.88

                            ORGANIC    WRNTY/ORG
ACQUISITION                 3400000.    3400000.       (I)
INITIAL SPARING              213000.     203807.
REPLENISHMENT SPARES              0.          0.
CORRECTIVE MAINTENANCE       741623.     601375.
```

(continued)

FIGURE D-5
(continued)

```
PREVENTIVE MAINTENANCE       1025624.    1025624.
WARRANTY PRICE                            255379.
AGE                           235000.     185867.
ENERGY                       6033081.    6033081.
OVERHAUL                     1062213.    1018100.
DATA                           50000.      37321.
INVENTORY MANAGEMENT          386669.     197167.
OTHER                              0.      27321.

TOTAL                       13147208.   12985041.

AVG.MTBFS:  0 TO  4.0    4.0 TO 10.0   TOTAL
              499.6         499.6       499.6

INPUT CODE
? 25
PCTGW,PCTGO,PLIM
.05 0. .5
? 0,-.05,-.50
INPUT CODE
? -1
DO YOU WANT GENERAL DATA FILE PRINTED, 1-YES, 0-NO
? 0
DO YOU WANT EQUIPMENT DATA FILE PRINTED, 1-YES, 0-NO
? 0

INITIAL SYSTEM MTBF=  499.6  INITIAL ORGANIC SYSTEM MTBD=  490.1

ORGANIC FALSE PULL RATE= .019

SYSTEM COST-ORGANIC,WARRANTY = $  17000.  17000.

     INITIAL     COST PER SPARE SUB
SUB   MTBF      ORG.    WRNTY.
 1   2000.0      0.       0.
 2    666.0      0.       0.


  OPERATING HOURS AND INSTALL SCHEDULE BY YEAR FOR EACH BASE TYPE
BASE   # OF   OP HR     ACTIVATED SITES AFTER N YEARS
TYPE   SETS   PER MO    1     2     3     4     5     6
  1      3    160.     30    30     0     0     0     0
  2      1     80.     10    10     0     0     0     0

  PRINT CODE
? 1

TOT.# INSTALLS =  200  TOT.OPER.HRS. =     3283200.
```

(continued)

FIGURE D-5
(continued)

ORGANIC MTBF GROWTH

1 477.0924430383
2 465.7026689877
3 460.0976549106
4 456.9528790944
5 454.9217934312
6 453.417258208
7 452.2218192997
8 451.2300789782
9 450.3827966014
10 449.6433218338

AVERAGE ORGANIC GROWTH MTBF = 455.2

ORGANIC MAINTENANCE SPARES

SUB	SPARES	PCT.	COST
1	0	0.00	0.
2	0	0.00	0.

MODULE SPARES

SUB	MOD	QTY	SPARES	PCT.
1	1	1	10	5.00
2	1	1	20	10.00

TOTAL COST OF SPARE SUBS = $ 0.
TOTAL COST OF SPARE REP.MODULES= $ 230000.
TOTAL COST OF DAF MODULES = $ 0.

TOTAL SPARES & DAF MODULE COST= $ 230000.

WARRANTY PERIODS-TW,DEL,NP
? 1,1,10
OVERHAUL BASIS: 1 FOR OPERATING HOURS, 2 FOR YEARS
? 1

*** WARRANTY AT DEPOT LEVEL ***

TOTAL ORGANIC LCC = $ 13234164.

WRNTY YRS.	WRNTY LCC	SAVINGS/LOSS	WRNTY PRICE	AVG.MTBF
1.00	13190957.	43207.	82237.	483.
2.00	13106128.	128036.	132057.	491.
3.00	13044109.	190055.	193429.	495.
4.00	12988353.	245811.	255379.	497.
5.00	12933160.	301004.	391588.	499.

(continued)

FIGURE D-5
(continued)

```
   6.00          12901830.       332334.          381538.       499.
   7.00          12879322.       354842.          446137.       499.
   8.00          12857257.       376907.          511847.       499.
   9.00          12853503.       380661.          578869.       500.
  10.00          12845755.       389409.          647359.       500.
FULL W           12755152.       479012.
 INPUT CODE
? 0
 WARRANTY PERIODS-TW,DEL,MP
? 4,0,0
 OVERHAUL BASIS: 1 FOR OPERATING HOURS, 2 FOR YEARS
? 1



    *** WARRANTY AT DEPOT LEVEL ***


    WARRANTY/ORGANIC MTBF GROWTH

    1 499.6249062266
    2 499.6249062265
    3 499.6249062266
    4 499.6249062266
    --TRANSITION--
    5 498.6381757277
    6 496.989059968
    7 495.6787435905
    8 494.5917005165
    9 493.6629972871
    10 492.8524615985

    INITIAL WARRANTY SYSTEM MTBD=  490.1
    WARRANTY FALSE PULL RATE= .019


   WARRANTY SPARES
    SUB    SPARES    PCT.     COST
     1         0     0.00         0.
     2         0     0.00         0.

    DO YOU WANT MODULE SPARES DATA PRINTED, 1-YES, 0-NO
   ? 1
```

(continued)

FIGURE D-5
(continued)

MODULE SPARES

SUB	MOD	QTY	SPARES	PCT.
1	1	1	8	4.00
2	1	1	14	8.00

WARRANTY SPARES COSTS

	SUB	REP.MOD.	DAF MOD.	TOTAL
REQUIRED	0.	203807.	0.	203807.
VALUE	0.	0.	0.	0.
NET COST	0.	203807.	0.	203807.

DISCOUNT FACTORS
DISC1,DSCTW,DSC2,DSCTOT .8311 .6830 .5200 .6444

4.0 YEAR WARRANTY PRICE 255379.
PCT/YR PER INSTALLED SET 1.88

	ORGANIC	WRNTY/ORG
ACQUISITION	3400000.	3400000.
INITIAL SPARING	230000.	203807.
REPLENISHMENT SPARES	0.	0.
CORRECTIVE MAINTENANCE	811579.	604687.
PREVENTIVE MAINTENANCE	1025624.	1025624.
WARRANTY PRICE		255379.
AGE	235000.	185867.
ENERGY	6033081.	6033081.
OVERHAUL	1062213.	1018100.
DATA	50000.	37321.
INVENTORY MANAGEMENT	386669.	197167.
OTHER	0.	27321.
TOTAL	13234164.	12988353.

AVG.MTBFS:	0 TO 4.0	4.0 TO 10.0	TOTAL
	499.6	495.4	496.8

INPUT CODE
? 99

4.2 Identifying the Input Data

After the program has begun execution, the computer prints a banner:

WARRANTY LCC ANALYSIS

The computer then asks if the user has identified the input data files:

FILES CALLED? 0 FOR NO, 1 FOR YES

The procedures described in Subsection 4.1 include this identification (e.g., GET,TAPE1 = GFMEP). Therefore, the normal response to the query is "1".

In some circumstances, the user may not have correctly identified one or both data files. In that case, a response of "0" to the query will allow the user to reenter the file names.

The program can format and list the contents of the data files at the user's discretion. A response of "1" to the requests provides the appropriate listings.

DO YOU WANT GENERAL DATA FILE PRINTED, 1-YES, 0-NO

DO YOU WANT EQUIPMENT DATA FILE PRINTED, 1-YES, 0-NO

In the example, the sign-on sequence identified both files; therefore, the appropriate response is "1". Since listings of the files are useful for reference purposes, the responses to the print requests are also "1" (see B in Figure D-5).

4.3 Initial Status of Equipment

The model now uses various input data elements to compute and display some initial characteristics of the equipment. Specifically, the model determines initial system MTBF and MTBD (Mean Time Between Demands), organic false-pull rate, and system cost. The program also displays MTBF and cost data for each subsystem. Finally, the program shows the deployment and usage schedule for the equipment (see C in Figure D-5).

4.4 Organic MTBF Growth and Spares Requirements

The model then uses the MTBF growth inputs to calculate the annual population MTBF, as well as population MTBF for the system over its life cycle. At the subsystem and module levels, this information is used to calculate the spares requirements and cost for each subsystem and module. These calculations are based on the installation schedule and operating hours, which the program displays.

The print code allows the user to define the degree to which the model displays the above results. The user has the following print code options:

- PRINT CODE = -1: No details on spares costs are printed, except total values.
- PRINT CODE = 0: Subassembly data and summary module data are printed.
- PRINT CODE = 1: Subassembly and detailed module data are printed.

The section marked (D) in the sample listing shows a print code response of "1" and the resulting output.

4.5 Selection of Warranty and Overhaul Policy

The program now asks for warranty period information:

WARRANTY PERIODS-TW,DEL,NP

"TW" is the number of years in the initial warranty period; "DEL" is the increment in years to the initial warranty; and "NP" is a repetition count, or the number of times the increment is added to the original period. The sample response "1, 1, 10" ((E) in Figure D-5) says that the original warranty is for one year, but the analyst would also like to see life-cycle costs for 10 cases, including warranties of 2 years, 3 years, 4 years, etc.

The user also indicates his choice of overhaul policy:

OVERHAUL BASIS: 1 FOR OPERATING HOURS, 2 FOR YEARS

A response of "1" causes the calculation of overhaul costs on the basis of system operating hours over the life-cycle period. A "2" calculates the costs on the basis of system overhaul every N years during the life cycle. The sample response is "1".

The program responds with

WARRANTY AT DEPOT LEVEL

4.6 Summary Life-Cycle Costs

The model calculates and displays organic life-cycle cost as a basis for comparison with the costs generated for each warranty/organic combination. It then calculates the costs associated with each such combination and displays the information, together with the savings or loss relative to the organic cost, the warranty price, and the average system MTBF over the life cycle ((F) in Figure D-5).

The program displays this summary information when NP is greater than one (see Subsection 4.5).

4.7 Sensitivity Analysis

The user now begins the sensitivity analysis cycle. The program asks for an input code, the value of which directs the program logic according to the following schedule:

Input Code	Definition
-1	Branch to beginning of LCC analysis and skip input file read statements.
0	Branch to request for warranty coverage period data.
1	Input new data file names and branch to beginning of LCC analysis.
2,3,4,..,27	Branch to a data change routine; following input of data changes, a request for another code value is made so that multiple changes are possible.
99	Stops execution.

An input code of "-1" is used when a data change affects organic maintenance. A value of "0" is used when a different warranty coverage period is to be analyzed or a data change does not affect organic calculations. Table D-4 summarizes the codes for changing data values. An underlined parameter indicates that a change in the parameter value required a branch to the beginning of the LCC analysis.

An example of a change that always requires a branch to the beginning is Code 2, when either the MTBFs or Retest OK rates (or both) are changed. An example of a code that may require a branch back to the beginning is Code 25, when values of PCTGW, PCTGO, and PLIM are changed. If only the PCTGW value is changed, the branch can be made to the beginning of the warranty analysis, assuming that no other changes affecting organic maintenance costs have been made.

When a change code is requested, the model will print the parameter names requested for change. The model will then print the current value of the parameters below the printed names. The analyst may change any or all of the parameters, but he must always enter a value for each parameter shown, even if it is the same value.

4.7.1 Changing Warranty Periods

In the example G in Figure D-5). the input code of "0" directs the program to request new warranty period information. The response "4, 0, 0" indicates that the analyst wants to see a detailed analysis of a four-year warranty (recall that when NP$\leq$1, the model generates detailed, rather than summary, life-cycle cost information). The program then repeats the request for overhaul basis identification that was made earlier in E.

TABLE D-4
SUMMARY OF CHANGE DATA CODES

Code**	Data Change
2	MTBF Factor and Retest OK Rates: VFAC*, RTOKS, RTOKM
3	Not Repairable This Station Rates: PNRTSSO, PNRESSW PNRTSMO, PNRTSMW
4	Probabilities of Demand at Organizational Level: PSO, PSW
5	Probabilities of Maintenance Repair at Organizational Level: POSO, POSW, POMO, POMW
6	Base-Cycle-Repair Times and Crder and Ship Times: TBRCO, TBRCW, TOSS, TOSM
7	Depot-Repair-Cycle Times: TDRCSO, TDRCSW, TDRCMO, TDRCMW
8	Spares Cost Data: BMORT, VMOD, PUDAF
9	Contractor Average Labor Rate for Corrective Maintenance: CALRCM
10	Army Average Labor Rate for Corrective Maintenance: AALRCM(1), AALRCM(2), AALRCM(3)
11	Contractor Corrective Maintenance Man-Hours on Subassemblies: CCMML
12	Army Corrective Maintenance Man-Hours on Subassemblies under Full Organic Maintenance: ACMMLO(1), ACMMLO(2), ACMMLO(3)
13	Overhaul intervals in operating hours and deployment years and overhaul costs under organic and warranty: HBO, INTOV, OVERO, OVERW
14	Contractor Corrective Maintenance Man-Hours on Modules: CCMMM
15	Army Corrective Maintenance Man-Hours on Modules under full organic maintenance: ACMMMO(1), ACMMMO(2), ACMMMO(3)
16	Fuel Costs per Operating Hour Under Organic and Warranty: FUELO, FUELW
17	Contractor Average Labor Rate for Preventive Maintenance: CALRPM
18	Army Average Labor Rate for Preventive Maintenance: AALRPM(1), AALRPM(2), AALRPM(3)
19	Preventive Maintenance Rate, Organic: PMRO(1), PMRO(2), PMRO(3)
20	Preventive Maintenance Rate, Warranty: PMRW(1), PMRW(2), PMRW(3)
21	RIW Price Variables: RSK, PFT, DTP, RIWFP, TCOTHW
22	Inventory Management Data: NPCO, NPCW, CIM
23	Government "OTHER" Costs: OTHO, OTHW, OTHWO, YOTHO, CTRANS
25	MTBF Growth Data: PCTGW, PCTGO, PLIM
26	Spares Reliability, LCC Period, Discount Rate, Warranty Type: PSUFF, NY, DR
27	Test Good Probabilities at the Depot: TGDSO, TGDSW, TGDMO, TGDMW

*Each MTBF is multiplied by VFAC. **Code 24 not assigned.

The output for the detailed warranty analysis resembles that output for organic maintenance (see Subsection 4.4), except that the user chooses whether or not he wishes to see module spares results (see (H)). The model also breaks total cost for organic and warranty/organic into the various component categories ((I) in the listing).

The discount factors are DISC1, the average discount rate for the period (0, TW); DSCTW, the rate at the time of warranty/organic transition; DSC2, the rate for the period (TW, NY); and DSCTOT, the average rate over the entire life cycle (0, NY).

The model displays the warranty cost as a total value and also prorates it over all installed sets. The latter value is expressed as the percent per year per set.

4.7.2 Changing Parameter Values

The second sensitivity analysis in the example ((J)) shows the procedure when the user changes the value of an input parameter. The input code "25" indicates a desire to change MTBF growth data. The user enters the new data ("0, -.05, -.50"); the program responds with another request for an input code. The user does not desire any further data value changes; however, becuase one of the changes he did make involved a parameter that was underlined in Table D-4, the user responds with "-1". This causes the program to branch to the beginning of the analysis. The details of this section of the sample are identical to those discussed previously.

4.7.3 Signing Off

An input code of "99" ((K)) terminates the program.